# RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA,

## VOL. LXI, PART 1.

## 1928.

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# RECORDS

## OF

# THE GEOLOGICAL SURVEY OF INDIA.

Part 1] 1928. May

## GENERAL REPORT FOR 1927. BY SIR EDWIN PASCOE, M.A., SC.D. (CANTAB.), D.SC. (LOND.), F.G.S., F.A.S.B., *Director, Geological Survey of India.*

### DISPOSITION LIST.

DURING the period under report the officers of the Department were employed as follows :—

*Superintendents.*

DR. L. L. FERMOR — Placed in charge of office till the 19th April. Acted as Palæontologist from the 6th April to the 31st July 1927. Placed in charge of the Central Provinces and Central India Party and also temporarily of the Bihar and Orissa Party.

DR. G. E. PILGRIM — Acted as Palæontologist till the 5th April 1927. Left for the field on the 3rd April 1927 and returned on the 20th July 1927. Remained at headquarters and acted as Palæontologist from the 1st August 1927.

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| MR. G. H. TIPPER | Returned from the field on the 25th February 1927. Granted combined leave for two years and four months with effect from the 6th May 1927, and permitted to retire on the expiry of leave. |
| DR. G. DE P. COTTER | Returned from the field on the 14th March 1927. Granted combined leave for eight months from the 28th March 1927. Returned from leave on the 16th November 1927. Placed in charge of the Punjab Party; left for the field on the 23rd November 1927. |
| DR. J. COGGIN BROWN | Granted leave on average pay for seven months and twenty-five days with effect from the 1st April 1927. Returned from leave on the 7th November 1927; placed in charge of the Burma Party. |
| MR. H. CECIL JONES | Returned from the field on the 9th April 1927. Granted combined leave for ten months and seven days with effect from the 6th May 1927. Permitted to attend the meeting of the Second Empire Mining and Metallurgical Congress held in Canada in August 1927. |

*Assistant Superintendents.*

| | |
|---|---|
| MR. H. WALKER . . | Retired from service with effect from the 16th March 1927. |
| DR. A. M. HERON . | Returned from the field on the 3rd February 1927. Granted Study leave for nine months with effect from the 12th February 1927. Returned from leave on the 7th November 1927. Placed in charge of the Rajputana Party and left for the field on the 21st November 1927. |

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|---|---|
| DR. C. S. FOX | Returned from the field on the 9th June 1927. Left for the Giridih coalfield on the 12th July and returned to head-quarters on the 16th. Placed in charge of the Coalfields Party. Left for the field on the 1st October 1927. |
| MR. H. CROOKSHANK | Granted leave on average pay for six months and eleven days; availed himself of the same with effect from the 13th April 1927 from the field. Returned from leave on the 22nd October 1927. Attached to the Central Provinces and Central India Party and left for the field on the 7th November 1927. |
| MR. G. V. HOBSON | Returned from leave on the 6th November 1927. Attached to the Coalfields Party and left for the field on the 23rd November 1927. |
| MR. E. L. G. CLEGG | Acted as Curator of the Geological Museum and Laboratory till the 19th April 1927. Placed in charge of office from the 20th April 1927. |
| RAO BAHADUR S. SETHU RAMA RAU. | Returned from the field on the 1st May 1927. Attached to the Coalfields Party. Left for the field on the 15th November 1927. |
| RAO BAHADUR M. VINAYAK RAO. | Returned from the field on the 5th May 1927. Detailed for the investigation of the manganese occurrences in the Belgaum and Kanara districts of the Bombay Presidency and thereafter for the continuance of the survey of the North Arcot and Salem districts in the Madras Presidency. Left for the field on the 1st November 1927. |

| | |
|---|---|
| MR. E. J. BRADSHAW | Attached to the Burma Party; remained in Burma throughout the period. Placed temporarily in charge of the Party during the absence of Dr. Coggin Brown on leave. |
| MR. A. L. COULSON | Returned from the field on the 15th April 1927. Acted as Curator of the Geological Museum and Laboratory from the 20th April to 31st August 1927. Detailed for the investigation of the hill slopes around Naini Tal. Left for the field on the 3rd September and returned to headquarters on the 10th October 1927. Appointed Curator of the Geological Museum and Laboratory from the 12th October 1927. |
| MR. D. N. WADIA | Returned from leave on the 3rd November 1927. Attached to the Punjab Party; left for the field on the 18th November 1927. |
| DR. J. A. DUNN . | Returned from the field on the 21st April 1927. Attached to the Bihar and Orissa Party. Left for the field on the 30th October 1927. |
| MR. C. T. BARBER. | Remained in Burma throughout the period as Resident Geologist at Yenangyaung and official member of the Yenangyaung Advisory Board. |
| MR. E. R. GEE . | Returned from the field on the 14th March 1927. Granted combined leave for seven months and twenty-four days with effect from the 18th March 1927. Returned from leave on the 22nd October 1927. Attached to the Coalfields Party; left for the field on the 1st November 1927. |

| | |
|---|---|
| MR. W. D. WEST . . | Returned from the field on the 11th July 1927. Remained at headquarters during the rest of the period under report. |
| MR. A. K. BANERJI . | Returned from the field on the 7th May 1927. Acted as Curator of the Geological Museum and Laboratory from the 1st September to the 11th October 1927. Attached to the Coalfields Party; left for the field on the 1st November 1927. |
| DR. M. S. KRISHNAN . | Returned from the field on the 4th May 1927. Services placed at the disposal of the Department of Education, Health and Lands for a period of four months with effect from the 1st July 1927. Attached to the Bihar and Orissa Party; left for the field on the 15th November 1927. |
| MR. P. LEICESTER | Attached to the Burma Party, remained in Burma throughout the period under report. |
| DR. S. K. CHATTERJEE | Returned from the field on the 29th April 1927. Granted leave on average pay for twenty-four days with effect from the 4th May 1927. Returned from leave on the 28th May 1927. Attached to the Central Provinces and Central India Party; left for the field on the 7th November 1927. |
| MR. J. B. AUDEN . | Returned from the field on the 13th April 1927. Attached to the Coalfields Party; left for the field on the 3rd November 1927. |

| | |
|---|---|
| MR. V. P. SONDHI | Attached to the Burma Party; remained in Burma throughout the period under report. |
| MR. B. B. GUPTA | Appointed Assistant Superintendent, Geological Survey of India, with effect from the 1st November 1927. Attached to the Burma Party. |

*Chemist.*

| | |
|---|---|
| DR. W. A. K. CHRISTIE . | At headquarters. |

*Artist.*

| | |
|---|---|
| MR. K. F. WATKINSON . | At headquarters till the 10th July 1927. Granted leave on average pay for two months and fifteen days with effect from the 11th July 1927. Returned from leave on the 26th September 1927. Remained at headquarters during the rest of the period under report. |

*Sub-Assistants.*

| | |
|---|---|
| MR. B. B. GUPTA . . | Attached to the Burma Party. Promoted to the grade of Assistant Superintendent with effect from the 1st November 1927. |
| MR. D. S. BHATTACHARJI. | Returned to headquarters from field work in the Central Provinces on the 6th May 1927. Attached to the Central Provinces and Central India Party; left for the field on the 10th November 1927. |

MR. B. C. GUPTA . Returned to headquarters from field work in Rajputana on the 2nd May 1927. Granted leave on average pay for eighteen days with effect from the 12th September 1927 and permitted to affix the Puja holidays. Returned from leave on the 12th October 1927. Attached to the Rajputana Party; left for the field on the 17th November 1927.

MR. H. M. LAHIRI . Returned from field work in the Punjab on the 1st May 1927. Granted leave on average pay for three months and eleven days with effect from the 4th May 1927. Returned from leave on the 1st August 1927. Attached to the Punjab Party; left for the field on the 1st December 1927.

MR. L. A. NARAYANA IYER. Returned from field work in Bihar and Orissa on the 4th April 1927. Granted leave on average pay for two months and seven days with effect from the 6th April 1927. Returned from leave on the 13th June 1927. Granted combined leave for two years with effect from the 12th September 1927.

MR. P. N. MUKERJEE . At headquarters till the 11th October 1927. Granted leave on average pay for seven weeks with effect from the 12th October 1927. Returned from leave on the 30th November 1927. Remained at headquarters.

*Assistant Curator.*

MR. P. C. ROY . At headquarters.

*Field Collectors*

| | |
|---|---|
| N. K. N. AIYENGAR | Returned to headquarters after collection of specimens from the Punjab and Rajputana on the 21st April 1927. Granted leave on average pay for two months with effect from the 16th May 1927. Remained at headquarters. |
| A. K. DEY | Returned to headquarters after collection of specimens from Madras on the 17th May 1927. Detailed for the collection of specimens in Bombay. Left for the field on the 22nd November 1927. |

*Museum Assistants.*

| | |
|---|---|
| AUSTIN. M. N. GHOSH. | At headquarters. |
| D. GUPTA | At Headquarters till the 11th October 1927. Granted leave on average pay for one month and twenty-eight days with effect from the 12th October 1927. Returned from leave on the 10th December 1927. Remained at headquarters. |

The cadre of the Department continued to be 6 Superintendents, 22 Assistant Superintendents and one Chemist. Of the two vacancies in the grade of Assistant Superintendent, including the one caused by the retirement on pension of Mr. H. Walker, one was filled during the year.

## ADMINISTRATIVE CHANGES.

**Promotion and appointments.**

Dr. C. S. Fox was appointed to officiate as Superintendent from the 28th March 1927 to the 15th November 1927 *vice* Dr. G. de P. Cotter on leave, and again from the 16th November 1927 onwards *vice* Mr. H. C. Jones on leave.

Dr. Heron was appointed to officiate as Superintendent from the 7th November 1927 *vice* Mr. G. H. Tipper on leave.

Mr. E. L. G. Clegg was appointed to officiate as Superintendent from the 20th April to the 6th November 1927 *vice* Dr. J. Coggin Brown on leave and again from the 7th to the 15th November 1927 *vice* Mr. H. C. Jones on leave.

Mr. E. L. G. Clegg acted as Curator, Geological Museum and Laboratory till the 19th April 1927. Mr. A. L. Coulson acted as Curator till the 31st August 1927, when his duties were taken over by Mr. A. K. Banerji. The latter officer was relieved by Mr. A. L. Coulson on the 12th October 1927.

Dr. G. E. Pilgrim acted as Palæontologist till the 5th April 1927 when he was relieved by Dr. L. L. Fermor. From the 1st August 1927 Dr. Pilgrim again acted as Palæontologist.

Mr. P. Leicester and Dr. S. K. Chatterjee have been confirmed in their a, pointments as Assistant Si perintendents.

Mr. B. B. Gupta, Sub-Assistant, was promoted Assistant Superintendent with effect from the 1st November 1927.

**Retirement.**

Mr. H. Walker, Assistant Superintendent, retired from the service with effect from the 16th March 1927.

**Leave.**

Mr. G. H. Tipper was granted combined leave for two years and four months with effect from the 6th May 1927.

Dr. G. de P. Cotter was granted combined leave for eight months with effect from the 28th March 1927.

Dr. J. Coggin Brown was granted leave on average pay for seven months and twenty-five days with effect from the 1st April 1927.

Mr. H. Cecil Jones was granted combined leave for ten months and seven days with effect from the 6th May 1927.

Dr. A. M. Heron was granted study leave for nine months with effect from the 12th February 1927.

Mr. H Crookshank was granted leave on average pay for six months and eleven days with effect from the 13th April 1927.

Mr. G. V. Hobson was granted an extension of leave for thirty-five days with effect from the 7th October 1927.

Mr. E. R. Gee was granted combined leave for seven months and twenty-four days with effect from the 18th March 1927.

Dr. S. K. Chatterjee was granted leave on average pay for twenty-four days with effect from the 4th May 1927.

Mr. K. F. Watkinson was granted leave on average pay for two months and fifteen days with effect from the 11th July 1927.

Mr. B. C. Gupta was granted leave on average pay for eighteen days with effect from the 12th September 1927.

Mr. H. M. Lahiri was granted leave on average pay for three months and eleven days with effect from the 4th May 1927.

Mr. L. A. Narayana Iyer was granted leave on average pay for two months and seven days with effect from the 6th April 1927 and was again granted combined leave for two years with effect from the 12th September 1927.

Mr. P. N. Mukerjee was granted leave on average pay for seven weeks with effect from the 12th October 1927.

## LECTURESHIP.

Mr. E. L. G. Clegg continued as Lecturer on Geology at the Presidency College, Calcutta, till the 31st October 1927 when he was relieved by Mr. A. L. Coulson. Dr. M. S. Krishnan acted as a wholetime lecturer on Geology at the Forest College, Dehra Dun, for a period of four months from 1st July 1927.

## POPULAR LECTURES.

A popular lecture on "A Geological Excursion to the Canary Islands" was delivered in the Indian Museum by Dr. L. L. Fermor during the year.

## LIBRARY.

The additions to the Library amounted to 4,628 volumes of which 1,215 were acquired by purchase and 3,413 by presentation and exchange.

## PUBLICATIONS.

The following publications were issued during the year under report :—

1. Records, Vol. LIX, part 4.
2. Records, Vol. LX, part 1.

3. Records, Vol. LX, part 2.
4. Records, Vol. LX, part 3.
5. Palæontologia Indica, New Series, Vol. VII, Memoir No. 3.
6. Palæontologia Indica, New Series, Vol. IX, Memoir No. 2, Part I.
7. Palæontologia Indica, New Series, Vol. X, Memoir No. 1.
8. Palæontologia Indica, New Series, Vol. X, Memoir No. 2.
9. Palæontologia Indica, New Series, Vol. XIV.

## MUSEUM AND LABORATORY.

**Staff.**

Mr. E. L. G. Clegg was Curator of the Geological Museum and Laboratory from the beginning of the year under report until the 19th April. On the 20th April he was relieved by Mr. A. L. Coulson who remained in charge until 31st August. Mr. A. K. Banerji assumed the duties from the 1st September to 11th October and from the 12th October Mr. A. L. Coulson again resumed charge. Babu Purna Chandra Roy remained Assistant Curator throughout the year and Babus Austin Manindra Nath Ghosh and Dasarathi Gupta fulfilled the duties of Museum Assistants. During the absence of Babu Dasarathi Gupta on leave, his duties were temporarily performed by Babu Nabagopal Gupta. Babu Lekh Raj continued to act as Chemical Assistant to the Burma Party, Rangoon.

**Chemist.**

After his return from leave on the 2nd January, Dr. W. A. K. Christie continued his duties as Chemist throughout the year, remaining at headquarters for the whole period.

**Determinative Work and Analyses.**

The number of specimens referred to the Curator for examination and report was 676 of which assays and analyses were made of 46. The corresponding figures for the previous year were 396 and 53, respectively. Chemical work included analyses of gases, waters, coals, limestones, manganese ores, sillimanite-rocks, pyrrhotite, gedrite, juddite, gneiss, calc-gneiss and quartz-magnetite-rock.

**Beads from Mohenjo Daro, Sind.**

A collection of 150 well-preserved beautiful beads—not included in the above figures—was submitted for examination by the Archæological Survey of India. These were found during recent excavation work at Mohenjo Daro, in Sind, and are considered to be be-

tween 4,500 and 5,000 years old. The skill of the lapidary shown in the making of the beads so as to bring out their full beauty indicates a surprisingly advanced state of cultural development. The beads are mostly of agate, agate-jasper, jasper, onyx, bloodstone, amazon stone, chalcedony and jade. The writer is preparing for the Archæological Survey a note upon the sources of the minerals found at Mohenjo Daro

A specimen from near Jogipalli Shrotriem (14° 13′ : 79° 44′) in the Madras Presidency has been identified as one of the gahnite group of zinc-spinels, a group of very uncommon occurrence in India.

**Gahnite.**

During the year an inventory was taken of the number of specimens exhibited and stored in the collections of the Geological Survey of India. The following figures are of interest:

**Number of specimens in the Museum collections.**

| | Total Number. | Number exhibited in the Museum. |
|---|---|---|
| Minerals interesting from a scientific point of view. | 11,960 | 4,220 |
| Minerals interesting from an economic point of view. | 4,690 | 4,690 |
| Meteorites . . . . . . . . | 588 | 588 |
| Rocks . . . . . . . . . . | 44,160 | 3,730 |
| Fossils—Vertebrate . . . . . . | 26,780 | 3,270 |
| Fossils—Invertebrate . . . . . . | 197,270 | 47,890 |
| Duplicate rocks and minerals arranged in sets for educational purposes. | 14,950 | .. |
| TOTALS . | 300,398 | 64,388 |

During the year under review, collections of minerals were presented to the under-mentioned institutions :—

**Donations to Museums, etc.**

1. Department of Commerce, University of Allahabad.
2. Department of Botany, St. John's College, Agra.
3. Mineral Department, British Museum (Natural History).

4. Geological Survey of South Africa.
5. University of Calcutta.
6. Agricultural College, Lyallpur.

In addition to the above, the following specific presentations were made :—

1. Corundum to T. V. M. Rao, Esq., Geology Department, Imperial College of Science and Technology, London.
2. Talchir boulders to Prof. E. W. Skeats, University of Melbourne.
3. Glass-making materials to the Principal, Technological Institute, Cawnpore.
4. Bauxite to J. K. Chaudhury, Esq., Reader of Chemistry, Dacca University.
5. Tourmaline to the Indian Institute of Science, Bangalore.

Additions to Collections.

In addition to a large number of specimens collected by members of the Department, the following specimens were received and included in our collections :—

1. Raw coal, dried coal and a briquette, Yallourn, Australia. Presented by Diwan Bahadur T. Rangachariar, C.I.E.
2. Allachite, Sweden. Presented by Prof. P. Quensel.
3. Nasonite, Sweden. Presented by Prof. P. Quensel.
4. Finnemanite, Sweden. Presented by Prof. Quensel.
5. Dixenite with pyro-aurite, Sweden. Presented by Prof. P. Quensel.
6. Sarkinite, Sweden. Presented by Prof. P. Quensel.
7. Magneto-plumbite, Sweden. Presented by Prof. P. Quensel.
8. Langbanite, Sweden. Presented by Prof. P. Quensel.
9. Quenselite, Sweden. Presented by Prof. P. Quensel.
10. Hausmannite, Sweden. Presented by Prof. P. Quensel.
11. Braunite crystal, Sweden. Presented by Prof. P. Quensel.
12. Corundum crystal. Presented by the Director, Geological Survey of South Africa.
13. Chrome-garnet (uvarovite). Presented by the Director, Geological Survey of South Africa.
14. Hortonolite-dunite (a platinum-bearing rock), Lydenburg district, Transvaal. Presented by the Director, Geological Survey of South Africa.

15. Hortonolite-dunite in contact with chromite-rock. Same locality. Presented by the Director, Geological Survey of South Africa.
16. Volcanic ash, from Mt. Pelée, Martinique, West Indies. Presented by M. E. Gaudert, Pondicherry.
17. Garnet crystal in mica. Purchased.
18. Chapmanite, Ontario. Presented by Dr. T. L. Walker.
19. Collinsite, British Columbia. Presented by Dr. T. L. Walker.

Meteorites.

No falls of meteorites were recorded during the year under review. On the 28th November, however, a very fine specimen of a stone meteorite, weighing 8,632 grammes, was received for examination from the Mewar Durbar, Rajputana. This fell in the village of Lua (24° 57′ : 75° 11′), Begu *pargana* of the Udaipur State, between 3 and 3-30 o'clock, p.m., on the 26th June 1926 and was mentioned in the preceding General Report. A complete account of the stone will be published later.

Burma Laboratory.

During 1927 in the Burma Laboratory 111 specimens were received and reported on, of which 18 were quantitatively examined. The corresponding figures for 1926 were 98 and 13 respectively. The specimens examined included ancient ornaments and jewellery found by the Archæological Survey during the course of excavations at Hmawza (Old Prome); coal, iron ore, lead ore, tin ore and stibnite.

## DRAWING OFFICE.

The artist, Mr. K. F. Watkinson, remained in charge throughout the year, with the exception of two-and-a-half months when Babu Kali Dhan Chandra held charge.

Publications.

The amount of publication work passing through the Drawing Office has been steadily maintained, a noticeable feature of the work submitted for reproduction being the intricacy of the geological detail. The following plates have been prepared during the year: 21 plates for the Records, 37 plates for the Memoirs and 23 plates for the Palæontologia Indica.

The total number of impressions made for publication were 54,750. This work has involved the preparation of 206 separate fossil photographs and 265 separate fossil drawings.

The plates for two volumes of the Memoirs are ready for publication and plates for two more are in course of preparation.

Geological Map of India.

The preparation of the new geological map of India, scale 1 inch =32 miles, has not proceeded as rapidly as anticipated. Minor alterations to the geology and a modification in the method of reproduction have delayed the draftsmen, but the work is proceeding steadily.

Map section.

The card index catalogue of original geological maps has been finished and brought into use. Work on the reduction of the one-inch-to-the-mile surveys to the quarter-inch scale has proceeded slowly, 36 one-inch sheets having been finished. Coloured original maps are mounted on cloth when stored, and the repair of old and damaged maps provides constant work.

Photographic section.

The photographic section has been kept fully occupied both in the preparation of prints to illustrate officers' reports, and in the preparation of blocks for printing. The number of negatives registered and added to the collection during the year was 242 against 332 in 1926. The number of photographic prints made amounted to 1,344 against 1,676 in 1926.

## PALÆONTOLOGY.

Dr. G. E. Pilgrim continued to fill the post of Palæontologist up to the 5th April and again from the 1st August for the remainder of the year. Between the 6th April and the 31st July Dr. L. L. Fermor took charge during Dr. Pilgrim's absence in the Simla Hills. Sub-Assistant P. N. Mukherjee assisted the Palæontologist with routine Museum work and with the determination of specimens during the year with the exception of two-and-a-half months absence on leave. Museum Assistant A. M. Ghosh has been engaged under Dr. Pilgrim's supervision during most of the year in arranging, cataloguing and preparing a card index of the specimens in the Fossil Vertebrate gallery. A card index of the invertebrate collections is also being compiled.

During the year under review the following memoirs have been published in the *Palæontologia Indica*:—

(1) E. Vredenburg: "A Review of the Genus Gisortia with descriptions of several species." Memoir No. 3 of Vol. VII of the New Series.

(2) L. F. Spath: "Revision of the Jurassic Cephalopod fauna of Kachh." Part I of Memoir No. 2, Vol. IX of the New Series.

(3) F. R. C. Reed: "The Palæozoic and Mesozoic fossils from Yunnan." Memoir No. 1 of Vol. X of the New Series.

(4) M. Cossmann and G. Pissarro: "The Mollusca of the Ranikot Series (together with some species from the Cardita Beaumonti Beds) revised by the late E. Vredenburg, with an introduction and editorial notes by G. de P. Cotter. Memoir No. 2 of Vol. X of the New Series.

(5) G. E. Pilgrim: "A Sivapithecus palate and other Primate fossils from India." Vol. XIV of the New Series.

The following papers of palæontological interest have appeared in the Records:—

(1) "The Distribution of the Gault in India," by G. de P. Cotter. (Vol. LIX, pt. 4.)

(2) "The Age of the so-called Danian fauna from Tibet," by G. de P. Cotter. (Vol. LIX, pt. 4.)

(3) "On some fossil Indian Unionidæ," by B. Prashad. (Vol. LX, pt. 3.)

(4) "The Lower Canine of Tetraconodon", by G. E. Pilgrim. (Vol. LX, pt. 2.)

The following papers of palæontological interest have not been published this year but print-off orders have been issued for all of them, and they are expected to be published early in 1928.

Memoirs in the *Palæontologia Indica*:—

(1) L. F. Spath: "Revision of the Jurassic Cephalopod fauna of Kachh." Part II of Memoir No. 2, Vol. IX of the New Series.

(2) H. Douvillé: "Les Couches à Cardita Beaumonti dans le Beluchistan." Memoir No. 3, Vol. X of the New Series.

(3) E. Vredenburg: "A Supplement to the Mollusca of the Ranikot Series edited with notes by G. de P. Cotter." Memoir No. 4, Vol. X of the New Series.

(4) B. Sahni: "Revisions of Indian Fossil Plants. 1. Coniferales." Vol. XI of the New Series.

(5) H. S. Bion: "The Fauna of the Agglomeratic Slate Series of Kashmir." Vol. XII of the New Series.

(6) G. E. Pilgrim: "The Artiodactyla of the Eocene of Burma." Vol. XIII of the New Series.

Paper of palæontological interest in the *Records*:—

(1) "A Permo-Carboniferous marine fauna from the Umaria Coalfield," by F. R. C. Reed (Vol. LX, pt. 4).

During a part of the year Dr. G. E. Pilgrim has been engaged in a revision of the fossil Indian Carnivora. The collections of the last 15 years have brought to light specimens which not only add to our knowledge of species created by Lydekker, but also represent new genera and species. Amongst the latter the Mellivorine group of the Mustelids are particularly well represented, though the material is unfortunately fragmentary.

Dr. L. F. Spath continues his revision of the Cephalopod fauna of Kachh, and he, as well as Miss Muir Wood and Mr. L. R. Cox, is studying the Cretaceous fossils of Gault age collected in Hazara by Mr. C. S. Middlemiss and in the Samana range of the N.-W. Frontier by Major L. M. Davies.

Sub-Assistant H. M. Lahiri has been engaged during the recess in the final preparation for the Press of the late Mr. Vredenburg's manuscripts of the second volume of the Post-Eocene Mollusca of N.W. India. His work has consisted not in the revision of the descriptions of the species but in identifying the actual specimens as far as possible (many even now have not come to light) with the figures and descriptions, inserting their localities and horizons according to Mr. Vredenburg's latest nomenclature, rectifying the more obvious inconsistencies, and supplying numerous omissions of dates, references and the like. Registration numbers have now been given not only to such specimens as have been figured in the memoir but also to those unfigured specimens belonging to species which Mr. Vredenburg recognized in the Indian deposits, and which can be traced by his hand-written labels or descriptions. The entire series is now stored amongst the Geological Survey of India type collection, and is available for reference when required. The memoir has been unavoidably delayed owing to this work, but will be issued in the course of next year.

Last season Field Collector Aiyengar collected from the Kamlial stage of the Lower Siwaliks of Sadrial, near Khaur in the Attock district,

an almost perfect mandible of a species of *Conohyus*, probably *C.*, *sindiensis*. Of especial interest is the preservation of the base of the canine, hitherto unknown, which shows a cross-section no less strongly scrofic than that of the European species of *Conohyus*, and so entirely different from that of the other contemporary Indian pigs which have a verrucose or sub-verrucose cross section. This mandible forms the subject of a joint note by Dr. G. E. Pilgrim and Mr. Aiyengar which will in the first instance be communicated to the Indian Science Congress in January 1927 and subsequently be published in the Records of this Department.

Dr. Baini Prashad of the Zoological Survey of India, who has been studying the fossil *Unionidæ* in the Geological Survey collections has submitted a preliminary paper containing descriptions of three new species, *Lamellidens jammuensis* and *Indonaia mittali* collected by Mr. N. C. Mittal from the supposed Upper Siwaliks of Nagrota, Jammu, Kashmir, presented by the Maharajah Bahadur of Kashmir, and *Indonaia pascoei* collected by Mr. K. A. K. Hallowes from the Lametas of Nawapet, Hyderabad. This is published in the Records, Vol. LX, part 3.

From time to time specimens of fossil plants obtained in the course of survey operations have been sent for examination to Professor B. Sahni of Lucknow University. Amongst these a fossil fruit collected by Dr. C. S. Fox from the Tipam Sandstone, 22 miles from Silchar, Cachar, Assam, has been provisionally assigned to one of the *Juglandaceæ*. Some dicotyledonous leaves from the coal measures of the Naga Hills, also collected by Dr. Fox, prove to be identical with the species *Phyllites kamarupensis* Seward (*Rec. Geol. Surv. Ind.* Vol. XLII, p. 94, 1912) from the coal seams of Margharita in Upper Assam.

Amongst the numerous specimens kindly presented to the department during the year or submitted for determination the following deserve special mention.

Major A. L. Bacon, V.D., of the Burma Ruby Mines, Ltd., presented a number of fossil bones and teeth which were found in a *limestone cave on the eastern side of the* Mogok valley. Since teeth of *Stegodon occur amongst them* we must conclude either that the remains are of Pleistocene age or that the genus *Stegodon* persisted into sub-Recent times. It will be remembered that from another cave in the neighbourhood of Mogok, Mr. Bacon obtained

some years ago a skull of a carnivore which Sir A. S. Woodward described and referred to a new genus to which he gave the name of *Aelureidopus.*

Another Ursoid animal, which appears to be extinct, is represented in the present collection and awaits further study. The remainder of the collection consists of fragmentary jaws of pigs, deer and antelopes, which unfortunately furnish no precise data for specific determination. It is hoped not only that further collections may be made from these caves, which promise to yield an interesting fauna, but also that the geology of the caves and the nature of the cave deposit may be investigated before long.

Mr. A. H. M. Barrington, Conservator of Forests, Hlaing Circle Burma, submitted for identification a collection of fossils from the Pegu Yoma, the precise locality being the bed of the stream half a mile above Myauknigon (19° 32′; 95° 25′). The specimens were examined by Mr. B. B. Gupta who succeeded in specifically identifying all but a very few and assigned them to the Kama stage of the late Mr. Vredenburg's scheme of classification. Two specimens (*Cyllene* cf. *C. varians*, Cossm. and a *Clavilithes* related to *C. seminudus*) are probably new species and have been retained for further examination. The remaining specimens are of previously described species and include :—*Clavilithes seminudus* Noetl., *Conus* (*Lithoconus*) *odengensis* Mart., *Surcula* (*Pleurofusia*) *phasma* Vred., *Drillia* (*Brachytoma*) *buddhaica* Vred., *Pleurotoma* cf. *ickei* Martin., *Merica promensis* Vred., *Rimella* (?) *javana* Martin, *Drillia* (*Brachytoma*) *gabei* Vred., *Cidaris* spine, *Natica* (*Naticina*) aff. *Hauncillei*, Desh., *Pecten kokenianus*, Noetl, *Oliva* (*Strephona*) *australis*, Duclos var. *indica* Vred., *Olivancillaria* (*Agaronia*) *pagodula* Vred., *Dione protophilippinarum* Noetl. var. *orbicularis*, and *Ostraea* sp.

Some poorly preserved fossil specimens were obtained by Mr. D. Dale Condit of the Whitehall Petroleum Corporation from the oil-bearing strata of the Naga Hills, 3 miles south-west of Nichu Guard, a point on the Kohima road, 9 miles from Manipur Road Station. The fossil bed is said to be 2,000 feet or more above a Nummulitic horizon. Sub-Assistant P. N. Mukerjee has discovered a very close affinity between a few shells in the collection and *Cyrena* (*Batissa*) *crawfurdi*, a species which characterizes the topmost beds of the Pegus at Yenangyaung, Burma. This suggests that the Naga Hill bed may be of the same age.

Another small collection of fossils from Assam in an equally bad condition has been in the hands of the Palæontologist for examination. The locality is N. W. of Kanchanpur, about 25 miles S. S. W. of Badarpur, in the Cachar district and about 4 miles W. S. W. of Hailikandi. Dr. C. S. Fox visited it with Mr. H. M. Sale of the Burmah Oil Company and collected the specimens. Amongst them Mr. P. N. Mukerjee found only two which admitted in any way of specific determination. These are two species of *Meiocardia*, of which one is closely allied to *Meiocardia metavulgaris* Noetling, while the other is new. Noetling recorded the species *M. metavulgaris* from his zones of *Mytilus nicobaricus* and of *Meiocardia metavulgaris*, both from Singu, Burma. Vredenburg correlated the Singu stage with the Upper Nari of N. W. India and, therefore, regarded it as the equivalent of the Chattian of Europe (Upper Oligocene). Since the fossils occur in considerable numbers at this site it is hoped that better preserved specimens may reach us before long, which will permit of a more satisfactory estimate of the geological age. It will be remembered that Mr. Vredenburg attempted a provisional correlation of the Tertiaries of Assam in 1921 (*Rec. Geol. Surv. Ind.* Vol. LI, pp. 330-35), but the scarcity of fossils and the difficulties of geological investigation in this densely forested region gives an exceptional interest to fossil occurrences such as the ones which have been recorded above.

A collection of fossils made by Mr. R. D. Thomson from the Agglomeratic Slate series of the Bren spur near Srinagar, Kashmir, possesses considerable interest. In the first place the specimens come from a locality, in which though the Agglomeratic Slate series has been mapped by Middlemiss and Bion, no fossils except *Fenestella* have been recorded. In the second place the species are entirely different from those which Bion has described from other exposures (*Pal. Ind.* New Ser. Vol. XII). This difference may be due to a varying local facies, or to a different age. The latter explanation would accord well with Middlemiss' view (*op. cit.* p. 12) that these beds occur at varying horizons in the different sections. The third feature of interest is that undoubted evidence of glacial action in the Agglomeratic Slate is here found for the first time in the presence of striated and facetted pebbles. Mr. Middlemiss (*op. cit.* p. 4) has already suggested a glacial origin for the Agglomeratic Slate, but was on the whole inclined to reject it in favour of explosive volcanic action. *Reticularia lineata, Martiniopsis* and other Brachiopoda

occur in Mr. Thompson's collection as well as numerous Lamellibranchiata. It is proposed to have the collection described and figured at a subsequent date.

During the early part of the field-season, Sub-Assistant L. A. Narayana Iyer, was deputed to make a further examination of the patches of Upper Gondwana rocks along the East Coast with a view to obtaining, if possible, a more representative collection of the marine element of the mixed assemblage of land plants and sea animals. The outcrops are all east of the granite boundary and covered up either by laterite or black cotton soil. Exposures are poor and sometimes limited to material from recently dug wells. The beds are very thin, and have a gentle or rolling dip. Of the four groups of exposures enumerated by Mr. Bruce Foote three were investigated the Kandukur, the Ongole and the Vemavaram-Budavada. From the latter many specimens of plant remains and marine fossils were collected. The latter are not well preserved, but as their specific identification has not yet been attempted, it will be sufficient to enumerate the genera provisionally determined. These are *Leda*, *Lucina*, *Ostraea*, *Exogyra*, *Pecten*, *Aucella*, *Arca*, *Tellina*, *Cyrena*, *Lima* (casts), a doubtful *Trigonia*, *Cardium*, *Pronoella*, *Alectryonia* and *Mytilus*, *Patella* (several species, large and small), *Natica* (casts), several species of *Rhynchonella* and *Terebratula*, and fragments of belemnites and ammonites.

Mention was made in the last General Report of certain black disc-shaped markings collected by Mr. Jones in 1921 from the Vindhyan rocks of Neemuch and sent to various authorities in the United States for opinion. The opinion of Dr. C. D. Walcott, Dr. E. O. Ulrich, Dr. R. S. Bassler and Dr. C. E. Resser of the United States National Museum is that they are true fossils and definitely brachiopods agreeing most closely with forms of *Acrothele* from the Cambrian. Professor B. F. Howell, of Princeton University, on the other hand, is more in favour of their being plant remains, since, when heated, the shiny film of the fossil—which is evidently the only part of the original organism now remaining—glows and burns to a grey ash. A piece of the shell of a Middle Cambrian phosphatic specimen of *Acrothele*, when tested in the same way, did not burn. Professor Howell remarks on the fact that there is no certain evidence of a beak or of any of the other features characteristic of *Acrothele* shells. He suggests that if the Vindhyan fossils are animal, they might be flattened phosphatic

shells of very primitive, probably pre-Cambrian, snails, and that they also resemble somewhat the opercula of certain Cambrian pteropods. Their identification, therefore, is still somewhat doubtful, although there seems to be a general consensus of opinion that the specimens are brachiopods of *Acrothele* affinities. The Suket Shales in which they occur are found beneath the Kaimur sandstone near Neemuch. The Kaimur sandstone is normally the base of the Upper Vindhyans, but, according to Dr. Heron, in the Neemuch area the Kaimur sandstone is succeeded in descending order by the Suket Shales, the Nimbahera Limestone, the Nimbahera Shales, and a very local basal conglomerate at Khori and Malan, with no break in the succession. Dr. Heron would regard the above beds as a local downward extension of the Upper Vindhyans below the Kaimur Sandstone. An alternative view is to regard the Kaimur Sandstone as the lowest division of the Upper Vindhyans and the Suket Shales as the top of the Lower Vindhyans, the Nimbahera Limestone, Nimbahera Shales and Khori-Malan Conglomerate all finding a place in the Lower Vindhyans.

During the year presentations of fossils were made to the following institutions:—to the Indian School of Mines, Dhanbad, a series embracing representatives of most of the invertebrate orders and extending from the Cambrian to the Pliocene; to the Department of Zoology, Allahabad University, a similar series including a few vertebrate species: to the British Museum (Natural History) duplicates of fossil mammals, chiefly from the Eocene of Burma, and casts of certain mammalian skulls and jaws which it is intended to figure in future publications.

## MINERALOGY.

The chlorophæite series.

A doubt was raised during 1927 by Dr. Peacock of Glasgow whether von Waltershausen's term palagonite (1846) is applicable to the material to which this term has been applied in the Deccan Trap basalts and similar rocks in other parts of the world. Dr. Fermor, in his study of the basalts of Bhusawal, has already drawn attention to the similarity between chlorophæite (1825) and some palagonite, and a paper by him on the composition of chlorophæite is appearing in these Records. Using four analyses of chlorophæite from Nagpur, Edinburgh, Sgùir Mohr (Island of Rum), and the Giant's Causeway respectively, Dr. Fermor finds that the following

general formula can be devised to interpret these analyses:—

$$2\tfrac{1}{2}H_2O.5R_2O_3.20SiO_2+n(RO.H_2O)+(80-4n)H_2O.$$

The water in the last term is that driven off below 100° to 110°C., whilst the water in the other two terms is that driven off above the temperature mentioned. Designating these as non-molecular and molecular water respectively, Dr. Fermor points out that the above formula shows that in chlorophæite there is this curious relationship between non-molecular and molecular water, namely that for each increase of 1 unit of molecular water there is a decrease of 4 units of non-molecular water. The specific gravity and refractive index increase with the value of $n$. The palagonite of Iceland is found to conform to this formula and hence it is deduced that the term palagonite has been correctly used in the terminology of Deccan Trap basalts. The term chlorophæite has priority and if the use of either term were to be discontinued, it should be palagonite. Dr. Fermor advocates, however, that chlorophæite should be used in a strict'y mineralogical sense and that palagonite should be retained with a more comprehensive scope in accordance with which it implies not a definite mineral but rather a secondary hydrous rock of which chlorophæite may be one constituent. Palagonitisation is, then, the process by which this alteration is produced.

**Specific gravity-ash relationship of Bokaro coals.**

Some years ago whilst studying the coals of the Korea coalfield, Central Provinces, (Memoirs XLI, part 2, 1914), Dr. Fermor detected a definite relationship between ash contents and specific gravity. On taking up the geological survey of the Bokaro coalfield (1916-17) he found that a similar relationship applied to the coals of Bokaro. After eliminating certain discrepancies a definite empirical rule can now be formulated by the use of which it is claimed a prospector can determine in the field the approximate ash contents of specimens of coal. The rule is linear and is as follows:—

$$a=(g-k)\times 100,$$

where $a$=the ash contents of the coal, $g$=the specific gravity of the coal and $k$=the specific gravity of ash-free coal for the field. A paper on this suggestive and interesting subject is appearing in the Records of the Department (Vol. LX, p. 313).

## Empire Mining and Metallurgical Congress.

The second Triennial Empire Mining and Metallurgical Congress

was held in Canada in August and September 1927. Mr. H. C. Jones, Assistant Superintendent of the Geological Survey of India, was deputed to represent his department at the Congress, but has not yet returned from leave, nor submitted a report.

## Simla Hill States.

During the spring of 1927, according to plan, Dr. G. E. Pilgrim and Mr. W. D. West resumed work in the neighbourhood of Simla, the former mapping the country to the west of the Simla motor road, and the latter that between the Simla motor road and the Giri river.

The highly metamorphosed schists, quartzites, and carbonaceous limestone and phyllites of Simla and Jutogh, to which the name of Jutogh series has been given were found to form an isolated outcrop separated from the similarly isolated outcrops of Chail and the Chor. The boundaries of the outcrop have been followed north-west of Simla to Halog (Dhami State) and then south-east to about midway between the motor road and the Ashni river and thence back to Simla. Within these boundaries two carbonaceous bands have been recognized, though they have not everywhere been mapped. Both bands contain carbonaceous limestone at intervals, though in neither of them is it invariably present. These are considered to represent the same horizon repeated by recumbent folding.

The Jutogh series has been found to rest everywhere on the Chail series, though in Simla itself the latter thins out to some 30 feet, which were united by Oldham with the Jakko carbonaceous slates of the Jutogh series. The Chail outcrop, like that of the Jutoghs is isolated from the Chail beds of the Chor area; it extends, however, much farther to the south-east and almost reaches the Giri river. The composition of the beds closely resembles that of the Chail series of the Chor area with one important exception: namely, that a lower horizon than any seen east of the Ashni river is exposed almost continuously from that river to Halog. These lowest beds are grey slates and banded limestones. The latter were correlated by Medlicott with the Blaini on the Sairi road and were mapped as such by McMahon (*Rec. Geol. Surv. Ind.*, Vol. X, pp. 204-223 (1877)) wherever they occur.

Dr. Pilgrim now has little doubt that the banded limestone

west of the Tons and 7 miles S.E. of Chakrata is identical with this Chail Limestone and does not belong to the Jutogh series, according to the view which he previously held and which was mentioned in the last Annual Report (p. 22).

To the north-east of the Giri the characteristic quartzites and conglomerates of the Jaunsar series crop out in two bands on either side of and dipping under the Chail outcrop. Mr. West has shown that the Jaunsars of the Simla and Chor areas are almost separate, but not quite as is the case with the Jutogh and Chail series, since a very narrow outcrop of them runs across the deep bed of the Giri, where for the most part only the underlying Blaini or Simla Slates are exposed. Mr. West had already shown that the Blaini dies out between the Giri and Ashni rivers so that the Jaunsars rest on the Simla Slates. Dr. Pilgrim has found that on the same line to the north-west it reappears, but is very inconstant and always thin. On the other hand the northern outcrop of the Blaini, which Mr. West has followed from the Giri to Simla, generally displays that series in an uninterrupted and typical development.

Both the bands of Jaunsar mentioned above thin out and finally disappear, when traced to the north-east, and the overlying Chail beds overlap them on to the Blaini or Simla Slates. Along the same boundary south of Halog, Dr. Pilgrim has also identified a thin band of the Subathu series, consisting both of the limestone—here almost unfossiliferous—as well as of the basal pisolitic laterite.

The three unconformities, referred to above fully confirm the conclusion previously arrived at, that each of them represents the trace of a thrust-plane.

Dr. Pilgrim appears to have demonstrated that the Chail and Jaunsar outcrops are each isosynclines of which the north-eastern limbs are missing either wholly or in part. South-west of Halog, the area between the Jaunsar thrust and another thrust which is assumed to be the continuation of the Giri fault, is also occupied by an isosyncline, of which the core consists of Simla Slates with Jaunsars on either limb. This in its turn is thrust over a folded series of Blaini and Infra-Krol which structurally seems to be in continuation of the Krol Hill.

Dr. Pilgrim's interpretation of the geology of the country between the Mahasu ridge and the Shali peak differs considerably from Captain Palmer's, a brief account of whose work was published

in the General Report for 1920 (*Rec. Geol. Surv. Ind.*, Vol. LIII, p. 10). He regards the Nummulitic beds as unconformable to the Madhan Slates and folded in with them; the latter series are probably Jaunsar. The extensive outcrop of slates and lenticular banded limestones which overlie the Madhan Slates was correlated with the lowest Chail horizon, the upper beds of the Chails being represented between Matiana and Narkanda by phyllites, talcose schists and quartz-schists; the whole sequence is disposed in a series of isoclinal folds within which occasional beds of a white quartzite, correlated with the Jaunsar, have been pinched in. Half-a-mile from Narkanda these beds are overthrust by highly metamorphosed mica-schists which are correlated with the Jutogh series. Of Captain Palmer's two alternative suggestions (1) that the limestone and slate series is Eocene, (2) that it is older than and thrust over the Madhan Slates, Dr. Pilgrim supports the second. He claims to have recognized the thrust-plane between Mashobra and the Nauti river, where the Chail limestone and slate series rests on some carbonaceous slates which pass up conformably into the Shali Limestone. He favours an age for the Shali Limestone immediately succeeding the Simla Slates, and regards it as probable that the Madhan Slates (?Jaunsar) are thrust over the Shali Limestone and do not overlie it in normal succession according to Palmer's view. At the same time the evidence at present available is not sufficient for a definite pronouncement on either point.

On the other hand the Naldara Limestone is considered to occur as lenticles near the base of the Simla Slate series, and to agree lithologically, with the so called Kakarhatti Limestone north of Subathu.

It is unnecessary to describe this work in greater detail here since a paper on the geology of the area has been submitted by the two authors and will be published shortly.

It has been decided to depute another officer, Mr. J. B. Auden to assist in this interesting Himalayan work. Mr. West will complete the survey of the area adjoining Simla and proceed south-eastwards in the direction of Chakrata with the aim of joining up with Mr. Griesbach's work in Kumaon, while Mr. Auden, after his initiation to the rocks of Simla, will work north-westwards with a view to joining up with Sir Henry Hayden's surveys in Lahaul and Spiti.

## ECONOMIC ENQUIRIES.

### Building Materials.

Keonjhar State: Bihar and Orissa.

Dr. Krishnan notes that the shales of the Iron Ore series in Keonjhar State, Bihar and Orissa are usually plastic and generally useful for making bricks and pottery. In the granite area also the weathering products of the felspar are seen to be good clay, but they are not found in bodies of any size.

Lower Chindwin district, Burma.

Mr. V. P. Sondhi reports that exposures of a compact, bedded sandstone of the Pegu series occur along the Ywashe-Yinmabin road, west of Monywa (Sheet No. 84 N/1). The stone is suitable for ordinary building purposes and can be easily trimmed and shaped. It is largely used by the Public Works Department in revetments and bridges.

Compact rhyolitic tuffs and agglomerate occur along the same road and are largely used as soling stone and road metal. They are found to withstand the local traffic in a satisfactory manner.

**Limestone and Marble, Sirohi State; Rajputana.**

Mr. Coulson describes a big spread of limestones and associated calcic rocks in the south-eastern area of Sirohi State, Rajputana. The purer varieties will only be utilizable when the present difficulty and cost of transport have been successfully dealt with.

Mr. Coulson noted a white marble at Ghoratankri (24° 22′ 30″ : 72° 54′) on the border of Sirohi State with Danta State. This rock has been quarried in the past as a building-stone and takes a good polish. The amount, however, is limited and the rock is very variable in texture and quality; furthermore the deposit is some 12 miles from the nearest railway station (Abu Road) and means of communication are very poor. An analysis showed the rock to have 16·16 per cent. of insoluble residue and 70 per cent. of MgO.

Mr. Coulson noticed a white saccharoidal marble in the vicinity of Perwa and Serwa (24° 37′ : 72° 36′) where it is quarried for use as a building-stone and to a lesser extent for lime. A sample from Perwa gave 8·52 per cent. of insoluble residue and 0·91 per cent. of MgO. The rock is not a good building-stone but occasionally blocks up to 8 feet long and $1\frac{1}{2}$ feet across are quarried; most of the stone goes to Sirohi City, some 23 miles to the north-east.

Two outcrops of a white saccharoidal marble, separated by mica-schists, were found by Mr. Coulson at Piloti (24° 32′ : 72° 28′) in Sirohi State. This is burnt for lime; it is useless as a building-stone on account of the absence of well-defined joints, but takes a good polish. An analysis showed it to contain 3·17 per cent. of MgO and 3·96 per cent. of insoluble residue. What is probably the same rock is found at Maraichi (24° 31′ : 72° 30′), in three isolated outcrops to the south-west of Godwara (24° 33′ : 72° 27′ 30″) and to the north-west of Bhilra C (24° 32′ : 72° 27′ 30″).

## Clay (See Building Materials).

## Coal.

Lower Chindwin district, Burma.

Mr. B. B. Gupta reports that outcrops of coal were seen in the Yaw rocks in two localities, one of them half a mile north-north-west of Goonyibin Sakan (22° 15′ 30.″ 94° 36′) on the Goonyibin Letpetin-road, the other in the Kyochin Chaung, about two furlongs north-east of Kyochin. In Mr. Gupta's opinion these beds are of no economic value.

Attock district : Punjab.

Some worthless vertical seams of carbonaceous shale, with strings of coal, were found in gypsiferous shales interbedded in the Lower Nummulitic limestones near Surg village about 9 miles W. S. W. of Campbellpur in the Attock district of the Punjab. The greatest thickness of the carbonaceous shale and impure coal is 2¼ feet.

## Copper.

Lower Chindwin district, Burma.

Mr. V. P. Sondhi records the occurrence of veins and impregnations of malachite and chalcanthite in the volcanic tuffs and agglomerate of Hill "937", west of Monywa. The deposit was opened up by Messrs. Jamal Brothers but the workings have been abandoned. The occurrence is about four miles north-west of, and similar to, that described in the General Report for 1926 (*Records, Geol. Surv, Ind.*, Vol. LX, pp. 27-28).

## Engineering and Allied Questions.

**Rangoon Hydro-Electric & Water Supply Survey, Toungoo and Salween districts, Burma.**

Mr. P. Leicester was deputed to accompany the Rangoon Hydro-Electric Survey Party to report on the dam sites, reservoir areas, tunnel lines, etc. of the Lewa-Pyagawpu area of the Rangoon Water Supply and Hydro-Electric Scheme. The country traversed lies within the Survey of India one-inch-to-the-mile sheets, Nos. 94 B/16, 94 F/3 and 94 F/4, in the Toungoo and Salween districts.

The northern part of the area was examined and reported on favourably by Mr. E. L. G. Clegg in 1922, but the scheme has undergone some considerable revision since then and the Yunzalin Dam which gave the name 'Yunzalin Scheme' to the Project is not under consideration at the present.

Several alternative schemes were investigated by the Survey Party. The works involved may be included under the following heads:—

(1) Pyagawpu Reservoir Area with:—

Thelaw Klo main dam site.
Spillway into the Thelaw Klo.
Kailaw Klo stop-gap dam site.
Bilin stop-gap dam site.

(2) Upper Shwegyin Chaung Reservoir Area with:—

Alternative dam sites.
The low saddle spillway.

(3) Lower Shwegyin Chaung Reservoir Area with:—

Two alternative dam sites.

(4) Tunnel Lines:—

Upper Shwegyin Chaung Reservoir to Kwila with:—

Upper and Lower Syphon lines at Pokodo Auk.
Branch from (1) to the Power Plant site above the Lower Shwegyin Chaung Reservoir near the junction of the Malaw Klo with the Shwegyin Chaung.
Lower Shwegyin Chaung Reservoir (Malaw Klo) to north-east of Lewa.
Pyagawpu Reservoir to the Power Plant site in the Kailaw Klo Valley.

(5) Penstock Lines and Power Plant Sites:—

Alternative sites at Kwila.
North-west of Lewa.
In the Kailaw Klo Valley.

To summarise briefly the scheme as outlined by the Engineers, it is proposed to impound the waters of the Thelaw Klo and its tributaries by means of a main dam to the east of Pyagawpu and the Kailaw Klo and Bilin stop-gap dams. The water from this reservoir will be carried through a tunnel into the Kailaw Klo to join the waters of the Tiplu Law and the Kano Law and their tributaries, which will be impounded by means of the Upper Shwegyin Chaung Dam. Hence it is proposed to carry the water in a tunnel to the neighbourhood of Lewa and Kwila; after passing through a power plant and then through filter-beds, the water will be carried to Rangoon by a pipe line about 125 miles in length. It is also proposed to erect a power plant in the Kailaw Klo valley to receive the water passing through the tunnel from the Pyagawpu reservoir before it is finally discharged into the Kailaw Klo.

The Lower Shwegyin Chaung Dam comes under the heading of a separate scheme for the supply of electricity alone.

The rocks exposed within the area in order of their respective ages are:—

(4) Alluvium,
(3) Plateau Limestone,
(2) Granite, etc. intruded into (1),
(1) Chaung Magyi series.

The older gneisses described by Mr. Clegg as occurring farther north are not met with in this area.

(1) The Chaung Magyi series, as identified by Mr. Clegg, is represented by quartzitic slates, shaly slates and quartzites. All grades from a dark blue cleaved though broken slate to a hard, light coloured quartzite are seen.

In the northern part of the area a general strike N.-by-W. to S.-by-E. is maintained, and the dip varies in direction and amount. The series has been folded along axes running approximately N.-S. The Pyagawpu valley shows a westerly dip on the west and an easterly dip on the east and appears to be an eroded anticline. The contact-altered quartzitic rocks bordering the granite

in the south-western part of the area are jointed but have revealed no trace of their original strike and dip.

Near the granite contact the series is very highly metamorphosed. Near the junction of the Kano Law with the Shwegyin Chaung the slates are converted into schists and schistose slates, while, farther west towards Pokodo Auk, the metamorphism has been of a complex and severe nature.

In the Shwegyin Chaung below hill, "3,076" and about one mile south-east of Pokodo Auk, there are excellent exposures of gneissic quartzite and quartz schist. The gneissic quartzite has irregular crystals of quartz scattered in a groundmass of smaller quartz crystals and a little accessory felspar. Nests of pale brown biotite, chlorite and a little magnetite occur. The quartz schist has elongated quartz crystals showing strain, ranged in bands with interstitial chlorite and a little magnetite.

Passing northwards the rocks vary considerably but are what would be expected within the metamorphic aureole where a series of sandstones and quartzites, with interbedded shale, has been intruded by granite. They comprise: siliceous hornfels, felspathic hornfels (zeptynite), felspathic granulite, felsite, highly metamorphosed quartzite with pyrites and highly altered shale or slate. The whole is intruded by veins of quartz, aplite and some basic rock which has been converted into amphibolite.

From north-east of Lewa to the junction of the Kano Law with the Shwegyin Chaung granite is traversed and the Chaung Magyi series, into which the granite has been intruded, lies to the north. About a mile to the south-east of Pokodo Auk the Chaung Magyis descend into and cross the Shwegyin Chaung, south of hill "3,076", passing northwards across the slate series to Pyagawpu the granite reappears to the east and north-east of the Pyagawpu valley and the rounded radiating spurs of the granite hills contrast with the parallel ridges of the Chaung Magyis.

The granite occurs as fine and medium grained boitite-granite which may possibly represent two stages of intrusion. Associated with the granite are veins of quartz and aplite and dykes of dolerite and hornblende-granophyre with pyrites and hæmatite.

The Plateau Limestone, which is believed to be of Permo-Carboniferous age, occurs as small outliers resting upon the Chaung Magyi series. The rock varies from grey to blue and white crystalline limestone, veined with calcite, and occurs as jagged peaks with pre-

cipitous tufa-covered slopes. The occurrences mapped by Mr. Leicester are:—

(*a*) Either side of the Kailaw Klo, three miles due south of Pyagawpu.

(*b*) A small outlier in the Kailaw Klo valley south of (*a*)

(*c*) On the left bank of the Tiplu Law near its junction with the Shwegyin Chaung.

(*d*) In the bed of the Thelaw Klo at Pyagawpu.

There appear to have been two phases in the deposition of the Alluvium in the area traversed. The earlier alluvium is found to compose the low flat ridges in the valleys, and consists of gravel and sand capped by a thick layer of soil. The more recent alluvium is capped either by light brown earthy alluvial clay or sandy soil with layers of sand and gravel of a very much fresher and purer nature than that found on the higher ground.

The proposed tunnel lines including the various alternative routes may best be referred to under the following heads:—

(1) Upper Shwegyin Chaung Reservoir to Kwila with:—

(*a*) Upper } Syphon Lines at Pikodo Auk.
(*b*) Lower }

(2) Branch from (1) to the Power Plant Site above the Lower Shwegyin Chaung Reservoir near the junction of the Malaw Klo with the Shwegyin Chaung.

(3) Lower Shwegyin Chaung Reservoir to north-west of Lewa.

(4) Pyagawpu Reservoir to Power Plant Site in the Kailaw Klo Valley.

The tunnel lines were geologically examined with a view to ascertaining (*a*) the stability and immunity from falls and (*b*) the immunity from loss of water through leakage of the proposed tunnels.

(*a*) The tunnels, Nos. 1, 2 and 3, pass through granite except for about one mile of metamorphosed quartzitic rocks, belonging to the Chaung Magyi series, which are crossed by tunnels Nos. 1 and 2 near Pokodo Auk (97° 1′ 15″; 18° 14′ 32″). The granite is stable and the joints generally cross the tunnel lines obliquely.

The jointing in both granite and the quartzite at the Upper Syphon Line is extensive, and Mr. Leicester considers that the tunnel should be lined as a protection against falls and leakage for at least 100 feet on either side of each crossing. Two streams are crossed and this necessitates a total length of lining of 400 feet.

The tunnels should also be lined where they pass into the decomposed rock overhead, which they are likely to do if they pass less than 50 feet below the surface.

If the tunnel, No. 2, to the Lower Shwegyin Dam Power Plant (Malaw Klo) pass through the narrow point on the ridge (97° 0′ 50″; 18° 13′ 20″) the hillsides should be drained to prevent slips and further erosion by the temporary streams that are formed during the height of the rainy season.

(*b*) In the solid granite there should be practically no loss of water through leakage as most of the joints visible at the surface will be closed at the depth of the tunnel. Any open joints met with, however, together with the margins of quartz veins and faults, must be well grouted.

As already mentioned the tunnel at the Upper Syphon Line near Pokodo Auk should be lined on account of the number and character of the joints in both the granite and the quartzitic rocks which might give rise to falls. These joints which are open cracks in the rock, would, in Mr. Leicester's opinion, allow a great quantity of water to escape if the tunnel were not lined.

The assemblage of contact rocks grouped under the heading of quartzites and gneiss are hard; some, such as the siliceous hornfels, will not be easy to excavate. They are stable and impermeable, but a number of open joints may be expected and these should be well grouted to prevent loss of water through leakage.

The decomposed granite of the district probably extends to an average depth of 30 feet below the surface. It is porous and, where the tunnel passes into it, will require lining. This is particularly necessary where the tunnels enter and leave the ground. A loss of head on account of the friction caused by the rough surface of the granite is anticipated.

Tunnel No. 4, from Pyagawpu Reservoir to the Power Plant Site in the Kailaw Klo valley, is 6,100 feet in length, has a direction N. 26° E.–S. 26° W., and passes through a ridge of shaly slate which has a general direction N. 20° W.–S. 20° E. The strike of the shaly slate is N. 15° W.–S. 15° E. The dip was nowhere visible, but it is presumed to be westerly in agreement with the dip of the slates in the same ridge further to the north.

The ideal section would be one in which the direction of the tunnel line were at right angles to the strike of the rock. In the present case the tunnel line crosses the strike obliquely at an angle

of 41° which should be sufficiently large for the stability of the tunnel.

Mr. Leicester remarks that there should be no necessity of lining for the prevention of falls in the hard slate, but where the rock is decomposed or soft, at the entrance and exit, the tunnel will need lining. The tunnel should have a circular outline and the walls should be made as smooth as possible to prevent the water under pressure from pressing into the cleavage planes of the slate and tearing off small angular fragments. It is presumed that the water passing through the tunnel will not carry large quantities of silt coarser than 0·2 mm. in diameter.

The tunnel should be satisfactory and safe from falls under a head of 50 feet as required. The rock is impermeable and there should be no fear of loss of water through leakage.

The rock at the Upper Shwegyin Chaung dam site is a medium grained biotite-granite traversed by dykes of hornblende granophyre and occasional quartz veins. The general direction of the joints is parallel to the direction of the dam line. About half-a-mile to the north and north-west slates overlie the granite; these are the slate facies of the series of quartzites and slates mentioned by Mr. Clegg in his report as probably belonging to the Chaung Magyi series.

Most of the granite at the dam-site is decomposed to considerable depths, and trial pits along the main dam line on the right bank reveal solid granite between 18 and 33 feet. On the left bank, which is particularly unpromising, no solid rock has been reached. The slope, unlike that on the right bank, is backed by a very steep ridge rising to a height of 4,000 feet above sea level. The lower slopes are partly composed of scree, and the granite has been greatly decomposed by the water collected on the ridge behind. It seems that all this water does not reach the main *chaung* by streams but soaks into the hillside which forms the left bank of the Shwegyin Chaung at the dam site. The decomposed granite is porous and, owing to its sandy nature, is liable to be washed down by running water except where is thickly covered with vegetation.

The uniform nature and extent of the decomposed granite renders it comparatively immune from slips, the only danger being that of the washing away of the loose material near the surface. The decomposed rock on the right bank is more compact and therefore more stable. The ground above the dam on either side should

be drained as far as possible in order to minimise further decomposition and prevent water from soaking into the dam from the side.

From a geological point of view Mr. Leceister considers the line to be unfavourable. The construction of a dam upon debris and semi-porous granite is objectionable, and to reach solid rock the foundations on thel eft bank would have to be sunk to a considerable depth.

The alternative line, across from the small stream-course on the right bank above the main dam lines to the stream-course on the left bank, reveals bare rock throughout nearly the whole length. The granite in the small stream-course on the right bank is a little crushed and one or two porous fractures are visible. If, however, the foundations of the centre wall of the dam are sunk well into the rock there should be no trouble from leakage. This line has the disadvantage of necessitating a long and irregular dam. In the case of a line from the stream-course on the right bank straight across to the rising ground on the left bank, although there is considerable saving in length of the dam, the rock on the left bank at this point is little better than that on the same side at the main dam line.

On the right bank the depth at which sound rock will be found is known. It is revealed by the pits on the main dam line. It seems that the best line would be one from the stream-course on the left bank across to the hillsides on the right bank.

The bed of the Upper Shwegyin Chaung Reservoir, from the dam line up to Longitude 97° 6′ 30″ and up to the Kano Law $\frac{1}{8}$th mile from its junction with the Shwegyin Chaung, is composed of granite. Slate occurs from Longitude 97° 6′ 30″ up the Shwegyin Chaung to the junction with the Tiplu Law. The rock up the Kano Law is slate, and slate forms the bed of the Kailaw Klo within the Reservoir area except for some limestone just north of the meeting of the Tiplu Law with the Shwegyin Chaung. This limestone is younger than the slate and overlies it. It should not be the cause of any leakage.

Mr. Leicester reports that both the granite and the slate are impermeable and are highly suitable for the floor of a reservoir.

The Tiplu Law flows on granite and through alluvium resting on the granite, but near the village of Kawleido (between Lats. 18° 15′ 5″ and 18° 15′ 20″) on the right bank of the stream, is a hill of limestone; this is apparently outside the reservoir area since the 2,000-foot contour is much lower down stream than is

shown on the one-inch map. Field evidence is slight but even if the water were to come up as far as this point it is unlikely that any considerable quantity would be carried out of the catchment area.

The banks of the reservoir are stable except at the end of the ridge on the right bank of the Shwegyin Chaung about one furlong north of the main dam line overlooking the stretch of alluvium through which the *chaung* meanders. Here slips had occurred and further slips may be expected, but these, it is thought, will be small and will not have any serious effect on the reservoir. The decomposed granite which forms the banks of the reservoir as far as the Kano Law is liable to be washed into the reservoir causing a certain amount of silting up if the vegetation here be not encouraged to grow down to the water level.

The trial pit on the low saddle passes through sandy and argillaceous decomposed granite and reaches a depth of $25\frac{1}{2}$ fee without striking solid rock. The argillaceous decomposed granite is impermeable or nearly so, but the sandy decomposed granite is porous. If an impermeable wall were made with its foundation in the clayey decomposed granite there should be no loss of water through leakage, but the comparatively soft rock will give slightly under any great weight It is difficult to say at what depth solid rock would be found if required. It should not be expected at a lesser depth than 50 feet.

For the Lower Shwegyin Chaung dam there are two alternative sites both of which are situated on fine-grained biotite-granite. On the upper line sound rock is exposed on the left bank but the right bank is composed of alluvium and talus with large boulders of granite resting on the granite. The dam foundations will of course have to be carried down through the superficial deposits which appear to be about 30 feet in thickness.

On the lower alternative dam line good medium to fine-grained biotite-granite is exposed on the right bank and on the left bank is the steep slope of a granite hill on which outcrops of granite are visible, there being but little decomposition of the rock. A large bed of boulders occurs in mid-stream.

The Lower Shwegyin Chaung Reservoir Area lies entirely on granite which is covered in places by talus with large boulders and alluvium. The granite is not highly jointed and although the joints cross the direction of the dam line obliquely, since they

are not open cracks, no water is likely to be carried from the reservoir.

The new Thelaw Klo dam line is farther down stream than the line examined by Mr. E. L. G. Clegg in 1922, being about $\frac{3}{4}$ mile N. E. of the V-shaped bend in the Thelaw Klo, S.E. of Pyagawpu (97° 7′ 4″ : 18° 20′ 5″). Outcrops of solid slate occur on either bank of the stream, the slopes of the valley are steep and stable and the hillsides are covered with trees and undergrowth. Trial pits on either slope have reached solid or nearly solid slate at reasonable depths. Though solid unaltered slate has not been reached in every case the rock met with is firm and impermeable and capable of bearing considerable weight. The weathered slate makes a good impermeable clay. This Mr. Leicester reports, is an ideal site for an earthern dam and should be satisfactory for a masonry dam provided with suitable foundations.

The site for a spillway into the Thelaw Klo is in a col situated 1,700 feet S. E., of the Thelaw Klo dam site. The trial pits which have been sunk along the line show soil and residual clay overlying decomposed slate on either side, and the centre pit which has been sunk to a depth of over 40 feet passes through brown residual clay. The rock is impermeable and the slopes of the valley are stable. The site is geologically satisfactory.

The site selected for the Kailaw Klo stop-gap dam is situated not so close to the divide as that previously inspected by Mr. Clegg. The rock here is slate with a strike N. 22° W.—S. 22° E., and a vertical dip. Tle trial pits like those at the spillway reveal clay and decomposed slate. The sides of the valley are stable and the clay and decomposed slate are impermeable. The site is satisfactory.

The new site selected for the Bilin stop-gap dam is farther to the south than that previously examined by Mr. Clegg. It is situated about $\frac{1}{4}$ mile N. W. of the point where the Bilin Chaung reverses its direction from a northerly to a souther'y route, about $2\frac{3}{4}$ miles S.E. by S., of Pyagawpu village. Trial pits show a capping of soil followed by alluvial clay with interbedded gravel resting upon the residual clay of the slate series beneath. To the south there is a sudden drop of 75 feet to the Bilin Chaung beneath, exposing a cliff face of slate capped by alluvial clay with interbedded gravel. It is here that the Bilin Chaung changes its direction from N.W. to S.E. by S. It appears that the upper

waters of the Bilin Chaung did not originally belong to that stream but flowed northwards into the Thelaw Klo along the now practically dry alluvium-covered valley in which the proposed dam site is situated. The Bilin Chaung must, in cutting its way back, have captured the upper waters of the former stream. It has since gone on cutting its way downwards through the alluvium and the underlying slates until at the bend it is now 75 feet below the valley of the former stream.

The trial pits appear to have passed through the alluvium and reached residual clay and, as the dam site is as much as 1,000 feet from the cliff face, there should be no fear of leakage of water through layers of gravel. The country rock is shaly-slate, the hillsides are stable and the clay met with impermeable, so that the site is satisfactory geologically.

The Pyagawpu reservoir area is contained in a long and broad valley, the northern portion of which runs N.—S. and the southern portion N.N.W. S.S.E. The Thelaw Klo meanders through this valley in a general westerly direction and is met by the Pele Law from the north and by a seasonal stream from the Bilin gap in the south.

The floor of the valley is covered by thick and fertile alluvium and the hills on either side consist of slate with a general N.-by-W. strike. The dip is steep and sometimes vertical; in general it is inclined steeply to the west on the western side of the valley and to the east on the eastern, thus indicating that the Pyagawpu valley is probably a denuded anticline, with its axis running N.-by-W. to S.-by-E.

In the centre of the valley blue and white limestone crops out in the bed of the Thelaw Klo. This limestone, like that in the Kailaw Klo valley and the limestone described by Mr. Clegg in his report on this area in 1922, would appear to be an outlier of the Plateau Limestone which originally covered the area. The limestone is situated completely within the reservoir area and, being younger than and lying on the top of the slates of the Chaung Magyi series, it cannot be the cause of any leakage.

Mr. Leicester finds that both the floor and the walls of the impounding area are impermeable. The alluvium is mainly argillaceous and only slightly arenaceous and the foundations of the dams will in any event be carried down to the impermeable slate series so that no leakage need be anticipated.

The slate series also forms the walls of the impounding area. The dip is outward but, as the series is quite impermeable and there is no trace of faulting, the rocks should prove quite water-tight.

The hill-sides are stable and not liable to falls with the exception of small unimportant earth slips which may occur on the west side of the valley just north of the site for the intake of the tunnel to the Kailaw Klo power plant. The reservoir area is reported as geologically satisfactory.

The Power Plant sites and Penstock lines examined were in every case satisfactory geologically. The Penstock lines, excepting the line in the Kailaw Klo valley, descend steep granite spurs covered by large granite boulders which appear to be firm and are not likely to fall except in the event of an earthquake of exceptional severity.

The line to the Power Plant Site in the Kailaw Klo valley descends a hill-side of slate which is stable and not prone to slips. The power plant site is situated on firm limestone near the left bank of the Kailaw Klo.

The Lewa-Pyagawpu area displays the most striking changes brought about by chemical decay or decomposition. Humic acids appear to be responsible for very considerable rotting of the rock. Mr. Leicester notes that, from a study of the trial pits sunk on the Upper Shwegyin Chaung and Thelaw Klo dam-sites, one cannot but notice the great depth to which the rock is decomposed on the thickly wooded hill sides, and the comparatively fresh condition of the rock in and near the banks of the streams where the ground is well drained and the rock washed by the comparatively fresh water of the streams.

It has been observed that though the trial pits sunk in the course of the work carried out by the Consulting Engineers in the Lewa-Pyagawpu areas originally reached solid rock, in many cases the rock at the bottom of the pits was found to have become soft after a short time. This is undoubtedly the result of the action of humic acid carried by percolating water. It appears, therefore, that in order to preserve the rock from decomposition it is necessary either to remove the vegetation which is the source of the acids or to design a system of drains which will prevent the acid surface water from coming into contact with works such as the shoulders of dams and the entrances and exits of tunnels. In the hot and very damp jungle of the reservoir area dense undergrowth springs up in a very

short time so that to keep the hill-slopes perpetually cleared would involve considerable labour and heavy maintenance charges. Mr. Leicester agrees with Mr. E. J. Bradshaw that in practice it will be found best to effect a compromise between the two methods.

Owing to the decomposed state of the surface rock the dams will necessarily have to be carried well into the hill-sides until solid impermeable rock is reached. The hill-sides above the engineering works should be very thoroughly drained in order, as far as possible, to divert the surface water from the works.

Besides the drainage system the ground in the immediate vicinity of the shoulders of dams and similar works should be kept stripped of all vegetation; in addition the ground at the entrances and exits of tunnels should be protected with concrete.

Before the reservoir is filled the basin should be cleared of weeds to prevent pollution of the water by a mass of decaying vegetation.

**Landslip in the Waller Gorge, Bawdwin Mines, Namtu, Burma.**

On the 6th August, 1926, a disastrous land-slide occurred in the Waller Gorge, near Tiger Camp of the Bawdwin Mines, Upper Burma, carrying away several houses and causing fatal injuries to forty-five persons. In response to a request from the Chief Inspector of Mines to the Geological Survey of India for advice as to the cause of the slip and the avoidance of similar accidents in the future, Dr. J. Coggin Brown was deputed to examine the ground in the month of March, 1927.

Waller Gorge contains the coolie quarter of Tiger Camp and is a narrow V-shaped valley formed by a small tributary of the Nam Pang Yun, the affected portion being close to its junction with the parent stream, and lying entirely within a group of rocks to which Dr. Coggin Brown gave the name "Pang Yun Beds" in 1914. These strata are in absolute conformity with the fossiliferous Lower Naungkangyis of Ordovician age above them, and pass without a stratigraphical break of any consequence into the Bawdwin tuffs and rhyolites below. They are quite unfossiliferous and their age is either Lower Ordovician or Cambrian. Quartzites, shales and slates of various kinds are the prevailing rock types with the former predominating in the vicinity of Tiger Camp. Owing to the proximity of the great overthrust fault of Bawdwin the quartzites are often broken up into small cleavage fragments, and there is other evidence of the severe shearing stresses to which the rocks have been subjected.

As a consequence of the steep easterly dip the eastern side of Waller Gorge forms a high scarp in which the broken edges of the Pang Yun quartzites are visible. On the western side of the gorge the smooth stratification planes of the quartzite can be seen dipping at high angles into the valley below. Where the dip is not too steep, the rock is covered by a variable thickness of light sandy soil, full of small fragments of quartzite. When the steep dip is taken into consideration, it is remarkable that these accumulations of debris can remain for long in the position they occupy, for there is little cohesion in the material itself. The surface covering the grass and vegetation doubtless acts as a protective agency in this respect.

The rainfall throughout Burma in August, 1926, was phenomenal and unprecedented. On the 14th, 15th and 16th a record total of eight-and a-half inches fell at Bawdwin Mine. After a careful examination of the site Dr. Coggin Brown came to the decision that water was the chief cause of the disaster, which he describes as a true soil-cap slip commencing possibly as a creep—the usual sequence of events in movements of this kind. He points out the necessity of distinguishing carefully between such soil-cap slips and true rock slides. In the case under consideration there was no movement of the underlying rock.

Weathered rock debris such as has been described above absorbs rain-water easily; the greater part of the water remains in the decomposed layer and, flowing along between its lower surface and the underlying quartzite, finally issues as springs at the bottom. The presence of large quantities of water in such material makes it more mobile, the springs commence to erode the "toe," and the coefficient of friction is reduced until the mass is in a state of unstable equilibrium. A heavier burst of rain completes the cycle; gravity asserts itself and the whole sodden mass slips down the slope, gathering velocity as it does so, until, like a flood from a breached dam, it sweeps all before its path. In the case under consideration about 150 feet of railway line, with sleepers complete, were carried away and seem to have exerted a plough-like action which accentuated the general destruction.

As a general rule the dips are inwards, towards the valley, and vary from about 45° to 75°; in exceptional cases the rocks are vertical, and there is some variation due to rolling and to the proximity of the overthrust. The dip is thus higher than the angle of slope

of the sides of the ravine. Particularly noticeable are the big expanses of smooth, almost polished surfaces of the stratification planes of the quartzites where the covering has been removed. Dr. Coggin Brown could find no evidence of any particular zone of shattering. He noticed that north of the slip the sides of the ravine are less steep and appear to have flattened to the angle of repose. The present slip appeared to him to be but a small incident in the host of similar events which took place on the hills around, many of them on a much larger scale.

Hill-sides formed by steep dip slopes and covered with porous soil caps cannot be regarded as stable in rainy weather in this region. At the best of times they are insecure; during torrential rains they become dangerous, particularly if a stream is eroding the foot of the slope. The hills around are undergoing active denudation and are changing their shapes and contours as quickly as natural agencies can accelerate the process. Phenomenal variations in the sub-aerial conditions to which such unstable systems are exposed must result in unusual consequences. The Waller Gorge slip was one of these.

In Dr. Coggin Brown's opinion drainage as a treatment for the case is rendered impossible by the local conditions at Waller Gorge and he suggests that dwellings which are in perilous situations should be moved to safer locations. He considers it unlikely that the present slip will extend, though a certain amount of loose material will be washed down during succeeding rainy seasons. To the north the ground is safer by reason of its lower inclination, while to the south a solid rock "toe" is exposed for some little distance down the line. As a precautionary measure Dr. Coggin Brown recommends the removal of the two barracks which at present occupy sites near the southern lower edge of the slip.

**Papanasam Hydro-Electric Project, Tinnevelly district; Madras.**

A scheme for the generation of electrical energy at the edge of the Cardamom Hills, in the Tinnevelly district, is under consideration by the Madras Government and Mr. W. D. West was deputed to examine the geological aspects of the scheme. Power is required chiefly for the establishment of paper mills near Papanasam. For this purpose it is proposed to conserve the waters of the Tambraparni river where it emerges from the hills by two reservoirs. The main reservoir will require a long and rather costly dam. It is more economical, therefore, to divide up the area into two parts

and to conserve the waters of the higher streams by a second reservoir further up the valley, for which a shorter and cheaper dam will suffice. This will enable the main dam to be kept as low as possible, and will at the same time utilise the whole of the catchment area.

The lower of these reservoirs will occupy the ground above and below Mundanthurai (77° 21′: 8° 41′), the suggested dam site being the narrow ridge of rock that cuts the main road about halfway between the second and third milestones. The dam site of the upper reservoir is situated a little south of the eighth milestone, where the river passes through a narrow gorge shortly after its junction with the Kari Ar.

As regards the lower dam site, its full height at the deepest point will be about 117 feet, and the length of the main deep portion about 3,000 feet. The rocks of this district are coarse-grained, gneissose biotite granites, rich in pink garnets. They strike W. 30° N.—E. 30° S., *i.e.* approximately parallel to the length of the dam. Mr. West reports that the rock is sound, but well jointed. The joints, though open at the surface, will probably be found to be fairly tight in depth, though trouble may be encountered locally. One or two pits have been dug along the site, and examination of them shows that the site is quite practicable. There is also a suitable saddle for the discharge of surplus water. The question of cost, however, is an important one in a scheme of this kind. As the rock is the same throughout the site, it is suggested that two deep trenches be dug right across it, rather than a number of small ones along the whole length. It is thought that the information obtained from these should be sufficient to enable the cost of the whole scheme to be estimated fairly closely. The local stone should be suitable for construction.

The dam for the upper reservoir will have to be about 185 feet high and about 850 feet long. This site also is parallel to the strike, and is located at a point where the valley narrows considerably, the constriction being due to a bed of charnockite which has been intruded along the strike of the country rock. The latter is mainly an acid gneiss and has a rather pronounced bedding which dips down-stream at about 25°, so that the charnockite outcrop is V-shaped, pointing down-stream a little obliquely. It thus comes about that the left flank will be entirely in charnockite, while the right flank will be partly in charnockite (the lower two-thirds) and

partly on the acid gneiss. It is not anticipated that the junction of the two rocks will be a source of danger, and the site as a whole was considered by Mr. West to be very satisfactory.

**Pinjikave Hydro-Electric Project. Palni Hills, Madura district : Madras.**

The Pinjikave Hydro-Electric Project is located in the Palni hills, 10 to 20 miles west of the hill station of Kodaikanal. The power obtained is likely to be used for the electrification of the railway in the Madura district. The project includes a number of schemes, all of which however, are not absolutely necessary for its success. The examination of the geological side of these schemes also was entrusted to Mr. W. D. West.

About 10 miles west of Kodaikanal a small reservoir is already in existence. This is situated on a low watershed, separating the streams with a N.W. trend from those flowing to the S. and S.E. The main idea is to impound the waters of the north-westerly-flowing streams by four dams, and to convey the water by a flume channel and a tunnel to the northern edge of the hills, where a fall of about 2,750 feet can be obtained. The four reservoirs are named: the Upper Koniar, the Lower Koniar, the Kodiyetanar and the Pulavachiar.

There is an alternative scheme by which the waters collected by the Upper Koniar dam can be conveyed into the existing reservoir, and thence by a channel for about a mile to the south-east of Berijam, where a fall of about 5,000 feet can be utilised.

The rocks throughout the district are nearly everywhere charnockite. The Lower Koniar dam site is the only exception. This rock has peculiar weathering properties, which have become emphasised by the very long period to which these hills have been subjected to denudation. When fresh it is a perfectly sound granite-like rock, usually well jointed. It is, however, sometimes found weathered very deeply, the weathering proceeding along the joints, so that cubical masses of fresh rock are left surrounded by completely decomposed rock. Mr. West remarks that it is thus not easy to predict from an examination of the surface of the ground the nature of the rock beneath.

The Upper Koniar dam site is situated at the end of a remarkably good reservoir site. Above the dam site the Koniar meanders through a wide, flat, alluvial valley, which is ideal for the formation of a reservoir. The construction of a dam here is, therefore, much to be desired. The dam will have to be about 70 feet high.

The rocks here, while apparently all charnockite, show a rather conspicuous bedding, striking along the stream and with a steep dip into the left flank. While the left flank of this site seems quite satisfactory, on the right flank the rock is deeply weathered and not at all suitable. There is a possibility of a better site further down-stream, but nothing definite can be said until excavations have been made.

The waters of this reservoir can either be used to supplement the waters of the other three reservoirs, or they can be used separately and conveyed into the existing reservoir at Berijam, and thence to the south-east to the head of the pipe-line. For the latter purpose it would be necessary to convey the water from the south-east end of the Berijam reservoir either by an open flume channel or by pipes. Information was required as to the possibilities of either method, for the course to be followed has been the scene of several landslips. Examination of the ground shows that landslips have occurred in the material formed by the disintegration of a banded gneiss. This process has proceeded very completely, forming a soft, bright red, powdery substance containing patches of kaolin. It is this material which has slipped, not the fresh rock. Mr. West, however, finds it impossible, to predict the depth at which solid rock may be found at any particular point. In the circumstances the alternative possibility of putting down a pipe-line would seem to be the only course, should it be desired to proceed with the scheme. This would of course be equally subject to the ill-effects of the slipping, but would have the advantage that it could be repaired more rapidly than an open flume channel, provided spare pipes were kept on the spot.

The Lower Koniar dam site is situated just below where the Kavinge-Kodaikanal road crosses the Talaivarai Ar. The dam is to be about 150 feet high and 800 feet long. This is the only dam site in this project that is not located entirely on charnockite. The rocks vary considerably, but they consist in the main of biotite-gneiss and charnockite, the latter varying from a very coarse siliceous variety to a fine-grained basic type. The strike of the rocks is parallel to the stream. The pits that have been dug indicate that, while the construction of a dam at this site is by no means impracticable, it is clear that it cannot be done cheaply. On neither flank does there seem to be any chance of finding solid rock up to the level of the top of the dam, however far one exca-

vated into the hill-sides. It is possible that the difficulties could be overcome by building only the central part of the dam to the full width, and extending the narrower flanks of the dam into the hill as a concrete core, founded on solid rock, but not necessarily ending against it. The suitability of 'this site for a dam really resolves itself into the question as to whether the enhanced cost of a dam on such a site is worth while.

The Kodiyetanar dam site crosses the Kodiyetan Ar close to the road to Kodaikanal. The site consists of two rather rounded hills, covered mainly with grass, but with rounded outcrops of rock scattered about here and there. A very complete series of pits supplies all the information required. The height of the dam is to be 150 feet. This area was once all massive charnockite.

It is now almost completely disintegrated; and the misleading outcrops of rock seen scattered over the surface of the hills are really relics of the once fresh rock left in a mass of soft earthy material, the disintegration being nearly complete. Mr. West reports that it is quite clear that any kind of large masonry dam is quite impracticable at such a site, and the scheme must evidently be abandoned, for there seems to be no better site.

The Pulavachiar dam site is situated a little way above where the Vandaravu path crosses the Pulavachi Ar. The stream here follows a fairly straight course through a narrow valley, the high and fairly steep sides of which appear to provide an excellent site for a dam, which is to be about 180 feet high. The rock is charnockite, and owing to the steepness of the ground seems to be quite fresh and sound. The site is a good one for a gravity dam, while there are also possibilities for an arched dam, the cost of which would be much less.

After the waters of these four reservoirs have been collected together, they have to be conveyed about three miles to the pipe line, and this involves the construction of a pressure tunnel, over a mile long, about three miles north-west of Kavinje. The rock forming the greater part, if not the whole, of the tunnel line is very probably charnockite. It is fairly well jointed, but appears to be sound, forming great vertical precipices. It has not the appearance of being deeply weathered, the topography suggesting masses of fairly fresh rock. Except for the jointing, which may give trouble in the way of leakage, the rock is thought by Mr. West to be probably quite suitable for the construction of such a tunnel.

It will be better, however, if the course of the tunnel be slightly modified, so as to allow both a greater cover and a greater horizontal distance of rock to intervene between the tunnel and the surface, to withstand the pressure at two rather weak points.

**Dam-site, Tungabhadra river, Bellary district; Madras.**

In response to a request from the Government of Madras who are considering the revival in a modified form of the old Tungabhadra Irrigation project, Mr. Vinayak Rao was deputed to report upon the geological aspects of the scheme.

The country near Timmalapuram on the Madras side of the Tungabhadra River has only one ridge which comes within half-a-mile of the river. The rest of the country slopes upwards to the hills some miles away. On the Bombay side of the river low hills extend along the northern bank and the hill mass of Shingtalur lies right on the bank of the river.

The rocks consist of Dharwar quartzites, schists and banded quartzites with conglomerates and diabase dykes. Though there appears to be a repetition of the beds, it is not likely to affect the foundation as the beds are dipping at high angles. On either side of the Dharwars are granites and gneisses. The dam would cut across the Dharwars almost at right angles to the foliation planes. According to Mr. Rao this is the only possible site for a dam for miles since, either up or down the stream, the dam would have to be undesirably long. Most of the beds here are impervious to water. The site appears to be a suitable one, but trenches would show the nature of the foundation and a further examination of these when constructed will enable conclusions to be more definite.

**Dam-site, Kolab river, Jeypore Estate, Vizagapatam; Madras.**

During the season Rao Bahadur M. Vinayak Rao was deputed to inspect the site selected for a dam on the Kolab river in the Jeypore Estate of Madras. The rocks at the proposed site consist of charnockites of the acid variety. They have generally a north and south foliation and are considered to be well suited for a dam site.

**Landslips, Naini Tal; United Provinces.**

In response to a request from the Government of the United Provinces Mr. A. L. Coulson was deputed to make a re-examination of the condition of the hills in and around Naini Tal in September and October. A

committee was convened to examine the whole question and to consider more especially the following points:—

(*a*) the maintenance of existing protective works;
(*b*) the need for further protective works:
(*c*) existing observation stations and the need for additional stations;
(*d*) lake regulation and the authority for its control;
(*e*) authority for excavation, building and tree cutting;
(*f*) the assessment of rain-fall run-off, normal leakage and evaporation;
(*g*) the verification of the catchment area and the question as to whether or not the Sukha Tal area should be included;
(*h*) the method of calculation of discharges and the assessment of a reasonable figure for the run-off;
(*i*) the method of recording rain-gauge readings:
(*j*) the removal of the large rock above the East Laggan road and near Killarney House:
(*k*) periodical inspection of the drains; and
(*l*) the examination of Charta Hill and Amparao.

The findings of this committee will be published in due course. Compared with other Himalayan hill-stations, Naini Tal has always suffered unusually from land-slip. The root of the trouble is a fundamental one, namely, the lesser degree of metamorphism undergone by the rocks composing the hill-slopes. The suggestion of the 1907 committee that the condition of the hill sides should be reported upon at intervals of not more than three years, is one worthy of support. With some of the other members in sub-committees Mr. Coulson considered in detail items *a*, *b*, *f*, *g*, *h*, *j* and *l*; in addition he submitted notes relative to China Hill, the Ballia Ravine, Kalakhan Hill, Durgapur Power House and the Depôt Road subsidence.

The chief reason for the constitution of the present committee lay in the fact that the Public Works authorities at Naini Tal were unable to account for about 70 per cent. of the water falling in the catchment area of the lake, the figure for the percentage run-off for 1925 being 30·4 per cent., the lowest on record. As this figure is regarded as the index figure for the safety of the settlement, alarm was felt at its extreme lowness, more especially so as the percentage run-off for 1918 was 82 per cent., there being a more or less constant diminution since that year.

In conjunction with Mr. Tunnicliffe, Mr. Coulson was able to account for 73·5 per cent. of the water falling in the catchment area, by allowing for various losses enumerated below:—

(1) The evaporation and absorption in the catchment area which, excluding the lake, equals 1095·5 acres, was calculated upon the basis of a "handicap" of 30 inches on the annual rainfall which in 1925 was 98·48 inches. It will be noticed that by adopting this figure, the run-off from the area works out at about 70 per cent., *i.e.*, 119,300,000 cubic feet.

(2) The evaporation losses from the lake at, say, 5 feet per annum amount to 26,245,000 cubic feet.[1]

(3) For losses from the lake by springs, the figure taken was 425 gallons per minute, being the mean of two previous estimations by Messrs. West and Hoey: these came to 36 million cubic feet.[2]

(4) The water taken for Municipal purposes and for Government House, during 1925, was 6 million cubic feet.

(5) The power-pipe discharges, as obtained from the Annual Report upon the Hill Sides around Naini Tal, equal 31,220,000 cubic feet.

(6) The discharge through the sluices and overflow (the figures being obtained from the same source as 5) amounted to 106,747,000 cubic feet.

Taking into account the correction for difference in lake level (7,191,000 cubic feet), the total water accounted for was 318,321,000 cubic feet. As the rainfall for 1925 equalled 434,691,000 cubic feet, the percentage run-off thus obtained is 73·5 per cent. approximately.

As the figures assumed for evaporation losses from the lake and absorption losses in the catchment area are based upon very approximate data, Messrs Tunnicliffe and Coulson did not think it advisable to take these figures into account in the annual calculations for the run-off. If these figures, accordingly, be neglected, a reasonable figure to expect for the percentage run-off in most years would be in the neighbourhood of 50 per cent. It was thought

[1] From a study of available records, Mr. Lyle assesses the annual evaporation from the lake surface as 3 feet 4 inches.

[2] Gaugings of the springs made after the above was written indicate that the probable losses by springs are about 140 million cubic feet of water per annum.

that little reliance could be placed upon the conclusions arrived up to date and future calculations of the run-off should be based upon more reliable data.

In a list enumerating certain additional protective works which were in his opinion advisable, Mr. Coulson mentioned amongst others: the removal of the large rock (Craig Ellachie) which overlooks the East Laggan rock; the provision of adequate drainage facilities on the threatened area in the vicinity of pillars Nos. A1, A2, B2, C2 and D2 on Kalakhan hill and the prohibition of cultivation in this area; the total demolition of Durga Cottage and the sloping-off of the hill-side, followed by afforestation; the drainage of Sukha Tal; afforestation on the slipped areas of Charta and Manora hills.

The rocks south of the fault line, which passes just below Glenlee, dip N. 30° E. at 45°; those north of it dip N. 35° E. at 16°. The rocks in the vicinity of Durga Cottage, therefore, have their maximum dip practically in the direction of greatest slope and less than the angle of slope. Conditions are thus exceedingly favourable for a slip. Great care should be taken of the drainage in the area from Glenlee to Edwinstowe; this region is as dangerous as the "dangerous area" of Sher-ka-danda hill.

The general dip of the rocks forming China hill and to the south-west of China is between 8° and 10° in a S. W. direction. If there were any general tendency to slip in this region, therefore, it would be to the far side of China away from Naini Tal. Shales with an interbedded band of dolomite form the hill; these shales are very well jointed and fractured, the resultant effect of two sets of cleavages. The result is that with water percolating along the cleavage planes and so dismembering the shales, fragments are continually falling. The scarped face towards Naini Tal is thus always tending towards verticality in its upper parts whilst there is an increasing apron of debris in the lower regions.

The safety of the lower end of Naini Tal down to Durgapur depends upon the Ballia ravine and its branches. At present the water in the Ballia flows under control to the Fairy Hall drain and thence onwards its course is free. In the first part of its course, the Ballia is not far distant from the lake fault and its general direction is the same. The dip of the shales forming the eastern slopes of the ravine is usually towards the river and as the angle of dip is generally less than the angle of slope, the conditions tend to instability. On the western side, however, the slates and shales dip

under the dolomite forming the mass of Ayarpatta and the conditions are far more stable. Thus steep slopes on the western side can be far more stable than less steep slopes on the eastern side.

Considerable trouble has lately been experienced on the western side of the Ballia between the Fairy Hall drain and the Coolie Lines drain. The barracks on the level ground above this region have been badly cracked and wisely vacated. Down the scarped face towards the Ballia numerous cracks have appeared in the surcharged revetment walls and a definite line of movement can be made out through the soil-cap of the main spur. Numerous slips have occurred in the lower part of this spur, the net result of which is to leave a scarped face which approaches verticality. The whole area is distinctly unsafe.

Rain-water, as usual, has been the chief destructive agent and the heavy rains of the current monsoon have added their quota of damage to that begun by the preceding rains. The soil-cap has become sodden with water and this has percolated through to the shales beneath. In addition, one of the lines of leakage from the lake exists almost at the junction of the shales with the dolomite at this point. There is thus abundant underground water available to make sodden the rocks of the spur in question. The Ballia also cuts away the toe of the spur and more soil and rocks subside to take the place of the material removed.

The dip of the rocks in this region is about 20° in a direction N.75°W. but whilst this tends to stability, the combined effect of the agents of destruction enumerated above has rendered the natural conditions powerless to prevent a gradual sinking of the spur.

Mr. Coulson did not think it possible to prevent the threatened slip and considers that a burst of three or four days heavy rain will bring about the fall of the bulged soil-cap and probably parts of the spur as far back as behind the first godown. When the slip has taken place, new revetment walls should be built and the flow of the Ballia and the Fairy Hall drain adequately controlled.

The Durgapur Power House was built upon the debris of the 1898 landslip from Kalakhan hill, already described by Mr. Middlemiss.[1]

Though the landslip foretold by Middlemiss has not yet taken

[1] Report upon the Kalakhan Landslip near Naini Tal, Government Press Calcutta, 1898.

place, the natural conditions are of great instability. The rocks of this region are very cleaved and shattered but the main cleavage direction seems to be towards the Ballia and the dip slightly less than the angle of slope. With the Ballia continually doing damage at the toes of the spurs, the conditions are ideal for a big landslip to occur. All that seems feasible is to take such preventive means as are possible to delay a slip which is probably inevitable and which will cause great damage when it does happen.

Charta hill was the scene of a destructive landslip on the 29th September, 1924, and the present trouble is in brief due to the difficulty in controlling the water flowing over the 1924 slip debris. Recent wash outs of debris have revealed rock *in situ* in the upper part of the main stream-course but its dip is not calculated to lend strength to the foundations of any proposed wall across the ravine in this region. In addition, the regions in the vicinity of observation pillars Nos. 1, 2, and 11 will shortly fall and cause destruction to the uppermost retaining wall. The whole site of the Brewery settlement is far from safe. Mention has already been made of the probable fall from Kalakhan hill; in addition, the spur of Charta to the south-west of the settlement is known to be conspicuously cracked. The spur between the Durgapur and Charta hill streams is far from safe and the spur overlooking the bridge on the Ranikhet side of the Ballia has recently cracked.

The subsiding area in the Depôt Road is in a valley between two small spurs of Kalakhan. Provided that adequate means are taken to prevent water entering the subsiding area at the fracture zone and in other places, Mr. Coulson thought it quite possible, though not of course certain, that further subsidence could be prevented.

Near mile 9 on the Kathgodam-Naini Tal road, much money has been spent upon constructive works to prevent further subsidence of the road but up to date, efforts have been unavailing. Mr. Coulson has described the geological conditions in this Amparao area in detail and has shown that though the argillaceous rocks at the main slip dip into hill " 3,300 " at about 7° in a direction N. 50°W., their physical characters are such that slips must take place. He also notes the existence of two faults in the area which have highly fractured the rocks and decreased their stability. The slipping surface is presumably the surface of the argillaceous material below the debris which is still *in situ*; this is kept lubricated

chiefly by percolation of spring water derived from rain falling upon a cultivated area behind the hill and water from several stream courses which pass over the cultivable area.

Provided that certain methods of drainage suggested by Messrs. Lyle and Coulson are followed and all cultivation stopped, it is thought that the slip may possibly heal itself in time if the main wall holds. Mr. Coulson did not think it possible to take the road higher up the slip face since sound foundations were not obtainable there. He also thought the expense of taking the road behind hill "3,300" would be prohibitive and it would add greatly to the length of road between Naini Tal and Kathgodam.

Mr. Coulson inspected a rough proposed alignment of the road on the other side of the Nalena river, and thinks that a road here is undoubtedly feasible, in spite of the fact that geological conditions are very similar to the Amparao side, except that on the Nalena side the rocks dip at higher angles than those on the Amparao side. There are thin bands of argillaceous shales interbedded with sandstone bands which will to a certain extent act as buttresses, but should surface water gain access to these argillaceous bands, it is quite possible that the history of Amparao may be repeated. Geological conditions across the Nalena were thought to be insufficiently favourable to warrant the abandonment of the present road and the latter should be maintained at least until proper drainage methods have been tried and found unavailing in the region above Amparao.

## Garnet.

**North Arcot district : Madras.**

Garnets are described by Mr. Vinayak Rao as plentiful in the gneiss one mile north of Kannamangalam (12° 45′ : 79° 9′ 30″ Survey sheet 57 P/1) in the north Arcot district of Madras, and might be useful for abrasive purposes.

## Gems.

**Mogok district : Burma.**

Historical records of gem-mining in the Mogok district of Upper Burma date from 1597 A.D., though the industry must have been in existence for a long period before that time. The Stone Tract was treated as a private estate of the Burmese Kings. A race of heriditary miners had evolved there and the methods of the Burmese administration, modified in accordance with the principles of equity, formed the foundation

on which the Upper Burma Ruby Regulation of 1887 was laid down, and on which the original lease, issued in 1889 to the Burma Ruby Mines, Ltd., was framed. The main features of this lease still persist. The interests of the indigenous ruby miner were fully safeguarded under the British regime. Licenses to win gems are granted to descendants of the old families and land for the purpose is allotted to them as occasion arises. For some years the company collected and retained the license fees, against which it paid a fixed rent and a proportion of its annual profits to Government, but since 1909 the royalties collected by the company have been accepted by Government (less 10 per cent. commission) in place of the fixed annual rental.

For some time the ruby market has been in a state of severe depression, and in 1925 the Burma Ruby Mines, Ltd., went into voluntary liquidation, after a chequered career of over 36 years. At the request of the Government of Burma, Dr. Coggin Brown visited Mogok in December last to investigate the situation and to make suggestions for the future development and control of the industry. He has submitted a report in which the history of the company, its financial affairs and its relations with Government on the one hand and the native miners on the other, are ably traced in detail, from the annexation onwards. Especial attention is paid to the technical progress which has been made, to the growth of modern methods of gem-mining, to the causes of the depressions which have periodically upset the market and to the competition of artificial gem stones.

Another part of the report deals with present and future mining operations by native methods, and contains recommendations regarding the following matters :— the issue of licenses, the restrictions limiting mining to an hereditary class, the liaison between the local authorities and the company, the complaints of native miners regarding the prohibition of explosives and machinery, tributing, the reservation of areas for the company, illicit mining, the curious local custom of *kanase*—by which women and girls enjoy the right to remove gems from stream-beds, tailings, races, and mine and washery dumps without the payment of fees—and finally, to the question of the staff which must be created to supervise native mining in case the Company expires.

The concluding section of the report deals with future mining operations by up to date methods. The present condition of gem-

mining in Burma is due to the cumulative effect of numerous adverse causes, but exhaustion of the gem-bearing deposits of the Mogok Stone Tract, as a whole, does not, in Dr. Coggin Brown's opinion, constitute one of these. The tract and the leased area extend over more than 600 square miles, the greater part of which is occupied by gneisses and associated rocks of Archæan age. Traversing them are great bands of crystalline limestone which stretch from the eastern bank of the Irrawaddy to beyond the longitude of Mogok. The sizes and positions of the more important of these have been demarcated on LaTouche's map of the Northern Shan States as far as a geological survey on a scale of one-inch-to-one-mile can exhibit them. A larger survey would probably reveal more of these limestone bands. From them most of the precious and semi-precious stones, and all the rubies and spinels, have been derived. (The sapphires, for which a brisk demand exists to-day appear to come from another source—a rock which may be of pegmatitic origin but which still has to be studied.) Their weathered products, released as the parent rock decays, travel down hill to the stream-beds where they accumulate in the water-borne gravels. It follows from the existence of gems in such situations that they must of necessity occur also in the detrital deposits of the hill-sides from which the true alluvials have been derived. The operations of the present Company, apart from early abortive attempts to mine gems from the limestone and a few inconclusive experiments on certain hill slopes, have been confined to removing and washing gravels from the Mogok, Kyatpyin and Kathe valleys. The actual system adopted is due to the work of Mr. A. H. Morgan who solved the drainage problem and so enabled the deeper deposits of the Mogok and other valleys to be treated on a large scale. There are, however, other valleys in the Stone Tract, in particular those of the Kin and Khabine, in which gems are known to occur, and which deserve fuller exploration than they appear to have received hitherto, with the object of proving their value as hydraulic mining propositions, rather than as areas to be opened up and mined by laborious, costly and slow hand methods. It was not until comparatively recent times that the present system of breaking down the working faces with monitor jets and raising the material so obtained by hydraulic elevators or gravel pumps superseded the older system. About the same time the rotary pans of the washing mills appear to have given place to modified forms of sluice boxes.

The greatest possibilities for the future, however, are believed to lie in the large scale treatment, on these lines, of the hill-side deposits and a stretch of country usually known as the "Western Slopes," in Dr. Coggin Brown's opinion, first merits attention. It is a somewhat indefinite area lying on that side of the ranges between Bernardmyo and Kathe which, judged by the amount of mining performed by natives in the past, is a gem-bearing region of great extent. It is stated that large parts of it could be reached by the cutting of the Bernardmyo ditch, a water channel surveyed under Mr. Morgan's direction in 1924.

Suggestions are made as to the new form of lease which should be substituted for the old one in case these or similar operations are undertaken in future.

## Gold.

**Lower Chindwin district: Burma.**

A minor industry in gold-washing is reported by Mr. B. B. Gupta to be carried on in the rivers of the Lower Chindwin district, Burma, flowing from the Paukin Chaung and draining areas covered by Irrawadian deposits. The villages of Pauktaik (22° 10′; 94° 47′ 30″), Thaminthat (22° 15′; 94° 45′ approx.), Zibindwin (22° 16′ 30″; 94° 50′ 30″ approx.), Tuywa (22° 24′; 94° 47′ approx.), and Nyaungbinle (22° 20′; 94° 39′ 30″) may be mentioned as places where gold-washing is carried on after the monsoon. The industry dates back to before the time of King Mindon. The daily output for each party of two or three men varied from $\frac{1}{8}$th to $\frac{1}{4}$ *tola* by weight of gold (nearly $22\frac{1}{2}$ and 45 grains, respectively).

Gold has previously been reported from Kani (Burma Gazetteer, Lower Chindwin District, p. 116; *Rec., Geol. Surv. Ind.*, Vol. XLIII, p. 250). Mr. Gupta did not hear of gold being actually washed at Kani but notes that the produce from the localities noted above passes through this village.

**Salem district: Madras.**

Auriferous quartz was reported to have been found at Matagondapalli (12° 37′ 30″; 77° 44′) about ten miles south-west of Hosur in the Salem district of Madras, where the rocks consist of the older gneisses intruded by the Hosur gneiss of Mr. Middlemiss, with included fragments of hornblende schists and some dykes. An assay in the Geological Survey laboratory of some of the quartz from this area, however,

showed no trace of gold. The chances are against the finding of gold quartz in this area.

## Iron.

**Keonjhar State: Bihar and Orissa.**

Several deposits of good hæmatite, derived from the banded hæmatite quartzite, were mapped by Dr. Krishnan during the season in the Feudatory States of Bihar and Orissa. Some of the best deposits are found along the Bonai-Keonjhar boundary.

The shales of the Iron Ore series in Keonjhar State yield, through weathering and segregation akin to lateritization, lumps and pockets of iron and manganese ores. Dr. Krishnan remarks that these are of irregular, but fairly wide, distribution. The ores are of a rather low grade, but experience in the adjoining area shows that they can be worked on a small scale.

**Northern Shan States: Burma.**

Ironstone mining in the northern part of the Federated Shan States is carried on by the Burma Corporation Ltd. and the ore so obtained is used in the blast furnaces at Namtu to assist in the reduction of sulphide ores containing lead, silver, zinc and copper. For this purpose they are essential, so that, although the quantities raised are small in comparison with those won in India to supply iron and steel works, the industry in the Shan States is a settled and important one and is likely to continue so for many years to come.

Early in 1927 Dr. Coggin Brown was requested by the Government of Burma to review the iron ore situation generally, and to pay especial attention to the questions of extension of known deposits and the possible occurrence of new ores, for it is desirable that the iron ore reserves should bear some comparable relationship to the very large quantities of metallic sulphides which have been proved to exist in the great Bawdwin deposit. He has examined the Manmaklang mine and the various workings centred around Pauktaw and Naungthakaw in the Wetwin region and, in a detailed report on these deposits, has briefly summarized our knowledge of other outlying ones, thus bringing up to date the observations of Messrs. P. N. Datta, T. D. LaTouche, E. L. G. Clegg and his own earlier work on this subject.

The Twinnge deposit was probably mined in the time of the later Burmese kings but Mr. P. N. Datta was the first geologist

to draw attention to the occurrence of iron ore in this neighbourhood (21° 57′ : 96° 25′) (Genl. Rep. *Geol. Surv. Ind.*, 1899-1900, pp. 121-122). In 1916 Dr. Coggin Brown concluded that the ore was of a residual nature and represented the ferruginous material originally disseminated through that portion of the limestone which has been removed by denudation since the Shan Plateau permanently emerged from the sea in later Mesozoic times. Further experience confirms these views (*Rec. Geol. Surv. Ind.*, XLVII, pp. 137-141).

The Manmaklang deposit lies in latitude 22° 50′, longitude 97° 40,′ and was described by Mr. E. L. G. Clegg in 1922 (*Rec. Geol. Surv. Ind.*, LIV, pp. 431-435). Dr. Coggin Brown does not accept the earlier opinions of the geologists of the Burma Corporation that it is of a residual origin, but regards it as a replacement deposit, the result of the action of iron-bearing waters of meteoric origin moving downwards through an exceedingly brecciated variety of the Plateau Limestone. Although Manmaklang still produces from 1,300 to 1,500 tons of limonitic ore per month, it is rapidly becoming an underground proposition in which operations cannot be carried on profitably in competition with surface work on the true residual deposits elsewhere.

The Kunghka ore body (23° 13′ : 99° 19′) is said to lie in a fault zone traversing rocks of the Pang-yung series and to have been formed by the infiltration of iron-bearing solutions, resulting in the production of solid hæmatite in a soft matrix of red and yellow limonite carrying specularite and barite. The Kunghka hæmatite is still mined and used in the production of copper matte only.

All the deposits of the Wetwin region are, in Dr. Brown's opinion, of residual origin. The Pauktaw quarry is close to the main railway line, some 4½ miles south-west of Wetwin station in the direction of Maymyo and about ½ mile from the log-washing plant of the Corporation. It was worked in 1920 and 1921. Originally the iron ore cropped out at the top of a small hill and as it was followed down, the excavation gradually increased to a depth of 35 to 40 feet. Abandoned now on account of the increasing thickness of overburden it still displays faces of red earth with shots of iron ore in its lower layers which overlie an ore bed 8 to 10 feet thick, massive in parts but more commonly possessing an "organ-pipe" structure. Bulk samples of this ore averaged from 56 to 57 per cent. of iron.

The abandoned workings of Bawhlaing lie some two miles to the north-north-east of Pauktaw camp and from them approxi-

mately 200,000 tons of good massive ore have been removed. It was a shallow deposit lying on the top of a limestone knoll showing the usual form of weathering. A typical analysis of the Bawhlaing ore shows iron 56·6, alumina 3·7 and silica 2 per cent.

Active work is to-day being prosecuted on the Naungthakaw lease, which is situated about latitude 22° 10′ and longitude 96° 31′, in sheet B/12 of the one-inch-to-one-mile survey, and six miles as the crow flies to the north-west of Pauktaw camp. It is on ground which slopes gently towards the valley of the Shwe-leik-ka to the south; to the west is the higher land, attaining elevations of over 4,000 feet along which the boundary between the Mandalay district and the Federated Shan States runs. The lease is divided into a number of separate sections. In section A the workable ores occur between 3,650 and 3,700 feet above sea level, varying from thin bands a few inches thick in the north-west and south-east to richer stuff, several feet thick, distributed in three well-defined patches in the middle of the southern half of the area. The average thickness of the overburden in an open cut is about 8 feet, and under this is 6 feet of vesicular hæmatite. In Section B, the best part of the ore bed lies on and about Kadut Taw hill (elevation 3,780 feet). Thinning out down the slopes, it becomes very evident again in Section C at heights of between 3,660 and 3,740 feet, with extensions into Section D. Much of the ore in these blocks is roughly rounded, rubbly material, rather than the cemented solid ore of Section A. The Corporation's Engineers estimated the original contents of Sections B, C, and D at 35,000, 50,000 and 6,700 tons respectively; these figures do not, however, include the whole of the ore bodies but are governed by the economic factors involved in profitable extraction by prevailing methods such as depth of overburden, thickness of the ore band and quantities of injurious compounds like silica and alumina.

An ore bed which commences in Section L and stretches across Section E at much the same contour levels is believed to contain some 35,000 tons. The open cuts display an extremely irregular surface of the underlying limestone, in the deep and narrow hollows of which pockets of brittle, rubbly hæmatite lie under 6 to 8 feet of overburden. Section M contains the southern portion of an ore bed which obtains its greatest development in Section I. Together they have been estimated to contain 66,000 tons. The overburden ranges up to 12 feet in thickness and the greater part

of the ore lies about the 3,700-foot contour. Details of the occurrences in the remaining sections are given in Dr. Brown's report.

Exploitation commenced in 1922, since when 35,000 to 40,000 tons have been removed *per annum*. All the work is opencast, large areas being stripped of overburden and the ore bed systematically removed. The larger pieces are hand picked, whilst the remainder is dry-screened on the spot, carted to Pauktaw, cleaned in a log-washing plant there and railed to Nam Tu. Operations are suspended during the rainy season. The washed ore as railed contains approximately :—

$FeO$ :— 71 to 72·5 per cent.
$Al_2O_3$ :—3·3 to 3·5 per cent.
$SiO_2$ :— 4 to 5 per cent.

The Corporation is engaged in a prospecting campaign in the surrounding country and as there are few surface indications of ore beds it is necessary to pit systematically across likely areas. Beyond advising the intensification of the pitting operations and an extension of preliminary pilot holes towards the north-north-east, Dr. Coggin Brown had no suggestions to make. As about 200,000 tons have been added to the available reserves as the result of the season's work, the present policy appears to be justified.

The prospects of obtaining large additional supplies in the embayment of the Plateau Limestone, covering a triangular area of about 420 square miles, with its base on the railway line between Maymyo and the Gokteik Gorge and its apex on the peak Hpataunggyi (3,564 feet) in Monglong, have been discussed by Dr. Coggin Brown. He believes that the origin of the red earth mantle can only be attributed to the accumulation of the insoluble matter in the limestone itself in the course of its degradation through weathering. If the red earth is a residual deposit its iron contents are also of the same origin. At one time disseminated in small quantities through the parent rock they were at first probably equally well distributed through the red earth, and their concentration into irregular beds towards the base of the clay is due to subsequent processes which have taken place in it since its formation. There are no signs that the iron ore formed any kind of concentrated deposit in the limestone, neither are there the slightest indications in this type of residual deposit that it is of swamp or lacustrine formation, or has been produced by any known kind of

replacement. It follows therefore that iron ore beds should be found in many suitable places both in this particular embayment and on the plateau generally, but the depth of the red earth must be sufficient for the chemical reactions which have resulted in the concentrations to have occurred, and the topographical conditions such that they have not been removed at later periods.

In 1915 Dr. Coggin Brown predicted the occurrence of ore between Wetwin and Padaukpin. It has been proved to exist but is of too bauxitic a character to be of any value in lead smelting. For some reason, which cannot be explained at present, the ores from the lower parts of the plateau and also the pisolites which frequently occur in the upper layers of the red earth, are often highly aluminous and it is to the higher geographical horizons and well drained gentle slopes at elevations such as those indicated that future attention should be directed. A zone of country possessing these features runs almost completely round the embayment, and it is in this, not far from the boundaries of the older rocks and yet not too close down towards the badly drained central area, that further extensions of these iron ore beds will be located. Such iron ore deposits are exceedingly irregular. The exhausted portions of the Naungthakaw blocks show how variable the surface of the underlying calcareous rocks may be. The general impression that it is a more or less level underlying table is entirely wrong for it is weathered into fantastic heights and hollows. One prospecting pit may miss the ore bed entirely, while the next one, landed on a hole in the limestone full of ore, may make an excellent and misleading showing. Close and careful pitting is essential before estimates can be attempted, while lines of pits should not be stopped because one or two holes yield poor results in succession. Instances are known in which a good ore sheet has thinned away to practically nothing down towards an insignificant surface drainage channel, to make again in quantity on the opposite slope.

Thaton district, Lower Burma.

Mr. P. Leicester was deputed to investigate the reported occurrence of rich deposits of iron-ore near Mokpalin in the Thaton district of Burma. The area, over which a prospecting license has been applied for is shown on the Survey of India ¼-inch sheets 94C and 94G. The claim lies in the foot-hills of the Kyaikto ridge east of the Sittang River in the Thaton district, and the area which has been prospected is about fifteen miles to the north-east of Mokpalin, a station on

the Moulmein branch of the Burma Railways, 80 miles from Rangoon. Only part of the area under consideration had been geologically surveyed; this had been done by Mr. P. N. Datta in the Field Season of 1908-09.

In passing north-eastwards from the sea up to the Kyaikto range the following rock series is traversed:—

Alluvium.
Laterite.
Thaton series (sandstones and shales).
Igneous rocks:—

Volcanic: Volcanic agglomerate.

Plutonic $\begin{cases} \text{Granite.} \\ \text{Contact-altered basic rock,} \\ \text{Epidiorite and talc schist.} \end{cases}$

Gneiss.

The sedimentaries of the Thaton series are covered with a thick cap of laterite in the neighbourhood of the coast but farther to the north-east there are frequent exposures of sandstones and shales with a general strike N. 20° W.—S. 20° E. and steep variable dip.

About six miles north-east of Mokpalin is a ridge known as Kyaukpon Taung, running N. 20° W.—S. 20° E., showing exposures of volcanic agglomerate. The stratigraphical relations of this rock are obscure but Mr. Datta[1] mentions "volcanic rocks, probably rhyolitic" as occurring in this ridge. The association of agglomerates and tuffs with rhyolite is a most natural and probable occurrence.

Mr. Leicester considers that the talc schists, which occur in various localities within the area, are probably derived through the alteration of basic or ultra-basic rock. Microscopic examination of the rock reveals talc with numerous small grains of magnetite partly decomposed to hæmatite.

There is a considerable area consisting of green metamorphosed basic rock and it is in this rock that the iron-ore occurs in the form of segregations of magnetite in irregular lenticular ore-bodies or lenses, which probably tend to run in a direction parallel to the granite contact. This rock appears to have been intruded as a basic product of differentiation from the parent magma of the granite of the Kyaikto ridge.

[1] General Report for 1910, *Rec. Geol. Surv Ind.*, Vol. XL, p. 108.

Dr. L. L. Fermor examined certain specimens and microscope slides of the basic rock submitted by Mr. Leicester and came to the conclusion that the original rock was probably an augite-plagioclase rock, possibly a gabbro, and considers that the green metamorphosed rocks may be classed as epidiorites.

Two occurrences of ore *in situ* have been discovered by the prospectors. These comprise rich segregations of magnetite about thirty feet in width with a general trend N. 20° E.—S. 20° W., but as yet no attempt has been made to discover the extent and true direction of the ore-bodies.

Elsewhere numerous pits have been sunk through the talus and soil-cap of the hill slopes. These pits have in many instances yielded detrital fragments of rich ore which have been derived from ore-bodies probably situated higher up the slopes.

The amount of proved ore is small but systematic prospecting should not only reveal the extent and nature of the occurrences already found but should also disclose some at least of the ore-bodies which are the source of the detrital fragments of ore scattered over the region. According to Mr. Leicester it seems probable, from the structural geology of the neighbourhood. that the ore-bodies are lenticular and that they run approximately parallel to the granite contact in a roughly north and south direction.

The ore is not in the form of veins or lodes and there is no indication of its having been thrust up into or having formed in fissures. It occurs, as has already been mentioned, in irregular, lenticular ore-bodies or lenses, originating apparently by concentration and segregation of the iron in the basic parent rock. This implies that the ore-bodies will in all probability be very irregular and of uncertain depth and their underground extent can only be accurately estimated by boring. The whole is capped, except in the stream-courses, by a considerable overburden of soil, laterite and talus which besides adding to the difficulty of prospecting will increase the cost of its extraction.

**Lower Chindwin district, Burma.**

Mr. Sondhi reports that in the neighbourhood of the village of Natyin Daung (Sheet 84 J/14) the *Plateau Gravel is remarkably rich in round, hollow, ferruginous concretions*, which appear to have been worked for iron by the villagers not long ago. Slag heaps were occasionally encountered during the course of the examination of the area, but active work has been discontinued.

**North Arcot district: Madras.**

Bands of Dharwars with magnetite were noticed by Mr. Vinayak Rao at Sottukinni (Survey Sheet 57 P/3) in the north Arcot district of Madras.

## Manganese (see also Iron Bihar and Orissa).

The manganese deposits of the Kanara district of Bombay were further investigated by Rao Bahadur M. Vinayak Rao, who reports a great development of manganiferous laterite in the neighbourhood of Castle Rock, extending some distance to the south. Manganese is found replacing some of the Dharwar quartzites at the Bhagavati mine about 2 miles south of Castle Rock.

**Kanara district: Bombay.**

Manganese is found in the laterite about 3 miles west of Anmod on the road to the Portuguese frontier.

To the south and south-east of Castle Rock manganese has been noticed east of Ku Vesi and in the hill between Kesarla and Titvali.

Psilomelane, pyrolusite and wad are usually the forms of manganese met with in this area. An analysis in the Geological Survey Laboratory of the Titvali manganese showed as much as 51 per cent. of manganese.

In the Belgaum district manganese occurrences are chiefly confined to the south-west part of the Khanapur Taluk. They occur in the laterite over the Dharwars which here have an rregular north and south direction. The chief places where workable quantities are found are: Talevadi, Amgaon, Jamgaon, Nerse and Kumbharda near Nagargalli.

**Belgaum district; Bombay.**

The ore occurs as a replacement mineral in laterite and occurs irregularly in blocks thereof. In Talevadi it is present below the laterite on top as well as in the valleys where a detrital laterite is found. It is also found segregated as thin bands along the stream-courses. Wad or the powdery form is found on the hill at Jamgaon, where it occurs as a fairly thick deposit of about 2-3 feet in thickness. In Jamgaon and Amgaon blocks of manganiferous laterite are found along the river valleys.

The laterite on hill-tops due to the alteration of Deccan Trap does not appear to have any manganese.

## Mica.

Mr. G. V. Hobson, whilst on study-leave in the United States of America, took the opportunity of making some enquiries regarding

mica, its distribution, utilization and consumption, and has submitted an interesting report upon the subject. Mr. Hobson was led to the conclusion that the mica-broker or middleman, although necessary to the trade, was absorbing a very large portion of the profits—a proportion sometimes well over one hundred per cent. This conclusion is confirmed by the surprisingly low average price obtained by the exporter of mica from India. The value for the years 1922, 1923, 1924 and 1925 averaged little more than Re. 1 per lb., the rupee at that time having an exchange value not far from 1*s.* 4*d.*

Mr. Hobson concluded that the elimination of the broker was only possible in the case of very large producing and consuming firms. One American firm has already achieved this result. The necessity of the broker arises from the fact that while the producer has for sale all sizes and grades of mica, the consumer in most cases requires only one or perhaps two sizes of one particular grade. This means that the producer, in order to dispose of his whole output, must be in touch with consumers of all classes, and must be prepared to carry heavy stocks. The producer is, in fact, very much in the hands of the broker, and frequently has to accept the price the broker offers him. Any producer attempting to do without the broker with respect to one or more sizes or grades of mica runs the risk of being boycotted by the broker with respect to the rest of his material.

One of the complaints made to Mr. Hobson regarding Indian mica was that occasionally a few cases of an order were found to contain mica of a different size from that ordered. The excuse made by the exporter would be that, owing to shortage, a case or two had to be filled with undersize mica and, to make up the average, a case or two filled with oversize mica. An examination of the consignment, however, always showed a balance in favour of the exporter. Another complaint was that Indian firms occasionally went back on their quotation and, on the receipt of a repeat order, attempted to raise the price. Mica consumers do not carry very large stocks and have no time for bargaining. Such correspondence as the above, therefore, usually meant a placing of the order elsewhere.

Mr. Hobson remarks upon the increased use of micanite, which is gradually replacing block mica in a number of uses. Two of the latter seen by Mr. Hobson were in the form of heater-units for

electric irons and lamp shades. Micanite is made from splittings, the production of which is at present almost a monopoly of India. In Schenectady Mr. Hobson was shown the latest development of the manufacture of micanite by machinery. Here mica-plate is being made with a new synthetic resin, which may prove a serious rival to the shellac hitherto used for binding purposes and derived from India.

During a visit to the Lacey mine in Ontario, the largest phlogopite mine in the world, Mr. Hobson was impressed with the efficiency of modern machine drilling and deep hole blasting. As the mica within the Indian pegmatites is much more scattered and the danger of damage to the mica correspondingly less, such methods should be eminently suitable for exploitation in this country. Skill is required in determining the blasting charge necessary to break the ground without shattering it.

There is undoubtedly a tendency towards the greater utilization of mica for almost any type of insulation problem. Micanite tape, flexible micanite, moulding micanite, heat resisting micanite, etc., can be used for such purposes, except where the insulating material must be poured into position.

Considerable efforts are now being made in South Africa and other countries to market a better dressed and graded product, and should this be accompanied by the training of the cheap labour available in the art of making splittings, the Indian position in the trade would to some extent be threatened.

## Monazite.

**Jeypore Estate; Madras.**

Mr Vinayak Rao noticed grains of monazite in the natural concentrates formed by the river Kalab, Jeypore Estate, Madras. As the area drained consists mostly of charnockite, it seems probable that the monazite was derived therefrom.

## Petroleum.

**Lower Chindwin district; Burma.**

Mr. B. B. Gupta, while surveying in the Lower Chindwin district of Burma, noticed a seepage of oil about half-a-mile north-west of Nyaungbinle (22° 20′; 94° 39′ 30″) in the Pondaung sandstone close to the faulted boundary. Two other seepages were noticed in the

neighbourhood and though not active at the present day there can be no doubt that they were so at no remote period. One of these seepages is understood to have been tested by a trial boring without any favourable result.

## Pyrites and Pyrrhotite.

North Arcot district; Madras.

The pyrites deposit of Polur in the North Arcot district of Madras, mentioned on page 50 of the Records of the Geological Survey of India, Volume LX, page 50, was further opened up by Field-Collector A. K. Dey during the field-season 1926-27. The pyrites occurs in lenticular bands between basic charnockites and quartzites of presumably Dharwar age, and is associated with a pegmatite. The width is about 4½ feet but is variable. Pits put down to a depth of 13 feet showed no diminution in width. Pyrrhotite was found in association with the pyrites which has been transformed into limonite at the surface and sides. Opal was found as a thin film on the surface of the pyrites, concentric in shape, showing secondary deposition at the surface.

An analysis of a sample of the pyrites in the Geological Survey laboratory, made by Field-Collector Dey, gave the following results:—

| | |
|---|---|
| $SiO_2$ | 17·28 |
| $Al_2O_3$ | 8·72 |
| $Fe_2O_3$ | 17·32 |
| Fe(sulphide) | 31·06 |
| Ni | Trace |
| $MnO_2$ | Trace |
| MgO | 1·02 |
| CaO | ·98 |
| $SO_3$ | 0·91 |
| S | 20·16 |
| $K_2O$ | ·18 |
| $Na_2O$ | 1·38 |
| $H_2O$ + | 1·40 |
| $H_2O$ | ·52 |
| | 100·93 |

This analysis and the one made by Mr. V. S. Rajagopalan (See *Rec. Geol. Surv. Ind.*, LIX, p. 50) give about the same amount of sulphur. The pyrites deposit occurs in lenticular patches and is likely to continue in depth.

## Refractories.

During the field season, Dr. J. A. Dunn made an examination of several deposits of aluminous refractories in Northern India, with the object of obtaining some idea as to the resources available in the country. During the last few years the minerals sillimanite and kyanite have been found to possess a particular value as refractories in the ceramic industries. It has been found that, on heating, these minerals change to a material called mullite ($3Al_2O_3.2SiO_2$) and a peculiar glassy material, in part cristoballite, the former occurring as an intricate network of lath-shaped crystals in the latter. If free $Al_2O_3$, *e.g.* corundum, is present, there is a greater amount of mullite developed relative to the glassy base. The resulting composite material has a rather low coefficient of expansion, high melting point, and considerable strength at high temperatures. Its peculiar properties render it ideal as a refractory material. So far as is known India possesses far greater resources of the minerals sillimanite and kyanite than any other country.

Assam.

The deposits of sillimanite and corundum in Assam occur in the neighbourhood of Sona Pahar north of the village of Nongmaweit in Nongstoin State. The area may be reached by motor lorry from Gauhati, 36 miles west as far as Boko, thence 12 miles south by bullock cart to Haima at the foot of the Khasi Hills, and finally some 2 days' march south into the hills for 23 miles. The area is on the Khasi Hills plateau and the height above sea-level is about 3,000 feet.

The sillimanite-corundum deposits are associated with such highly aluminous rocks as cordierite-biotite-quartz-microcline-gneiss and sillimanite-quartz-schists. The majority of the deposits consist mainly of massive sillimanite with a little corundum; one or two are almost entirely of corundum and several are entirely of sillimanite. Impurities are not abundant and consist mainly of rutile, a very little biotite, and iron ore. There are some thirteen different deposits occurring over a belt some 3 miles long by 1 mile wide. It is quite likely that the belt extends over a greater length than that surveyed.

In estimating the quantity of material available it is difficult to arrive at any definite quantity, owing to the peculiar "segregatory" nature of the individual deposits, and to the fact that a very large amount of the material is completely decomposed. However, reckoning down to a depth of only 10 feet for the majority of the

deposits, Dr. Dunn estimates that there is at least a total quantity of 83,000 tons available, including float ore. This must be regarded as an absolute minimum : the actual quantity could easily be many times this amount.

In judging their economic value the location of these deposits is a grave disadvantage, and under present conditions transport difficulties would make freight high.

Rewa.

The deposit of corundum-sillimanite in Rewa State, Central India, is near Pipra, a small village in the extreme south-east corner of the State, about 5 miles from its eastern and southern boundaries. The deposit is associated with sillimanite schists and pyroxene-bearing rocks. The bed of corundum is about half-a-mile long by about 70 yards wide. Reckoning on an average depth of 30 feet, the total quantity of corundum available was estimated by Dr. Dunn to be at least 100,000 tons. Of sillimanite the estimated quantity is 1,000,000 tons of very poor quality, with perhaps 100,000 tons of good material. The possibility of exploiting the better class sillimanite is, however, limited owing to its intimate admixture with the impure material. Apart from this latter fact, however, there is the additional disadvantage of the very high freight to Calcutta. At present it is carried by bullock pack to Mirzapur, some 120 miles. Transport costs could be considerably reduced by constructing a bullock cart track to the bank of the Son River, whence the material could be floated down the Son and Ganges Rivers on barges.

Bhandara ; Central Provinces.

The deposit of corundum and sillimanite in the Bhandara district of the Central Provinces is at the foot of a small hill about 1 mile south-east of Pohra village. This village is 3 miles as the crow flies south-south-east from Lakhni, which is 13 miles east of Bhandara town and on the main road. The hill is formed of a N.-S. striking bed of quartzite which dips to the west at a high angle and is flanked on either side by sillimanite-bearing muscovite-schists, the muscovite varying from merely an occasional constituent to the dominant mineral in the rock. Another rock-type associated is a fine-grained tourmaline rock usually containing sillimanite needles and traversed by veins of sillimanite. The massive sillimanite is found associated with this tourmaline rock, usually as veins or as irregular replacement masses up to 6 feet across. Such massive sillimanite was found only by Dr. Dunn at one point *in situ*, over an area of 40

feet by 50 feet, but debris indicates, perhaps, a wider distribution. The massive corundum was not found *in situ*; all the corundum now being obtained is found in the hill wash at the north foot of the hill over an area of 100 by 100 yards. Dr. Dunn considers the deposit to be negligible since the amount of ore cannot exceed more than 100 tons each of corundum and sillimanite.

**Barabhum ("Barahabhum"); Bihar and Orissa.**

In the neighbourhood of Rengadih near Barahabhum Station on the Purulia-Sini branch of the Bengal-Nagpur Railway, several occurrences of kyanite rock are found over a narrow east-west belt extending from about ¾ mile east of Salbanni to just south of Ichadih, a total length of about 7 miles. The rock with which the kyanite is associated is a mica-schist, occurring along the boundary of the Chota-Nagpur granite-gneiss. Indeed, some of the kyanite-rock was found to occur in mica-schist which is included in the granitic rock itself. The mica-schist is a pure muscovite-quartz-rock. Another associated rock is tourmaline-quartz, frequently banded, and often so riddled by white quartz that it has almost the appearance of a breccia. Tourmaline-rock is formed by replacement of the mica-schist. Dr. Dunn describes the kyanite rock as occurring in small irregular masses up to 6 feet in length in the mica-schist. Much of its seems to have been altered to muscovite by crushing and the addition of alkalies, and originally the kyanite-rock was probably far more abundant than now. A peculiar feature is the occasional, but rare, occurrence of crystals of blue corundum in the kyanite rock.

According to Dr. Dunn it is doubtful whether 100 tons of good material could be collected easily, and even if more could be obtained by closer prospecting and greater expense, the value of the material would be discounted by the amount of muscovite present.

**Singhbhum; Bihar and Orissa.**

There is a series of deposits of kyanite-rock extending over a belt some 70 miles long in the Singhbhum district, Bihar and Orissa, passing through the native States of Kharsawan and Seraikela, and the Dhalbhum sub-division. The main rock of this belt is a muscovite-schist, but hornblende-schist is very frequently met with. The mica-schist often contains large crystals of staurolite and garnet. Dr. Dunn observes that the rock with which the massive kyanite is usually associated is a kyanite-quartz-rock or granulite. At Lapsa Buru this rock is found in enormous beds, the massive kyanite apparently

occurring as segregations in the more acid rock. Very frequently, as a secondary alteration product of the kyanite, a topaz granulite is found. Corundum is a common mineral in the massive kyanite-rock. Rutile, as in all these aluminous deposits of Northern India, is also a constant constituent in the rock. There seems little doubt, according to Dr. Dunn, that these deposits are the metamorphic products of highly aluminous clays, and in some cases apparently of clays of a bauxitic composition.

The largest deposit is that at Lapsa Buru at the western end of the belt. Here, the debris alone would, according to Dr. Dunn's estimate, provide a minimum quantity of at least 234,000 tons of kyanite rock; this, however, is given as a very conservative figure, the actual available quantity being possibly 10 times this amount. Another good deposit is at Ghagidih, about 3 miles south of Jamshedpur, where over 20,000 tons are available.

At Rakha Mines there are perhaps several hundred tons of massive kyanite in the alluvium shed from the kyanite-quartz-rock. In the remainder of the belt to the south-east of Rakha Mines there is little or no massive kyanite-rock associated with the kyanite-quartz granulite, but the latter may find a market, in the future.

Bamra State; Bihar and Orissa.

The mineral from Balram in Bamra State, Bihar and Orissa (see General Report for 1925, *Rec. Geol. Surv. Ind.*, LIX, p. 51), originally thought to be sillimanite has, on closer investigation, proved to be tremolitic amphibole.

## Ruby (see Gems).

## Salt.

Sagaing district; Upper Burma.

Salt is of common occurrence in the Tertiary rocks of Upper Burma and in the past a considerable industry in salt working was carried on in the Sagaing district. Kadu Lake (22° 3′; 95° 33′) covers some 40 square miles and is a shallow, saline lake. In the past it appears to have extended further to the east and Mr. Bradshaw reports that traces of the old workings are still visible. Low hummocks in the soil-cap east of Padu mark the sites of the debris from the ancient sump holes and the fragments of multi-

tudes of pots are stratified in the soil. Salt is found in the Tertiary rocks which form the hills between Saye and Ondaw, as brine from wells and springs, and as an efflorescence in the sandy deposits which form the low ground At Padu a tube well was sunk some 100 fee in quest of water for the Agricultural Department experimental farm. Some 1,200 gallons per hour of saline water was obtained and it has been suggested that if the brine content be sufficiently high this water might be evaporated for the production of salt. There can be no doubt that the salt is derived from the Tertiary rocks. In the area examined by Mr. Bradshaw there was no active work in progress but in view of the large quantities of salt which are imported annually into Burma, the salt which occurs in this district might prove to be of economic importance if it were worked systematically.

## Sandstone (see Building Materials).

## Sapphire (see Gems).

## Spinel (see Gems).

## Sulphuretted Hydrogen.

**Lower Chindwin district; Burma.**

Springs charged with sulphuretted hydrogen were noticed by Mr. B. B. Gupta in the following localities of the Lower Chindwin district, Burma :—

(1) In the Sonda Chaung about one-and-a-quarter miles south-west of Nyaungbinle (22° 20′; 94° 39′ 30″);

(2) In the small river about one and a-quarter miles north-west of Thalauk (22° 15′; 94° 40′ approx.);

and (3) In the Yebowa Chaung, about three-and-a-quarter miles north-west of Kabaing (22° 12′ 30″; 94° 41′ approx.).

## Tin.

Mr. P. Leicester observes that the tin mined around Mawpalaw Taung (15° 52′; 97° 46′. Sheet 95 E/13) east of Karokpi in the Amherst district of Burma occurs in the lateritic eluvial deposits at the foot of the hill, which is composed of red, buff and white sandstone and banded quartzite associated with shales and micaceous slate. The ore which is chiefly grey cassiterite appears to be derived from small quartz stringers intruded into the sandstones during the period of granitic intrusion of the province. The tin has been concentrated in the eluvium of the hillsides and now appears scattered through the lateritic deposits in the vicinity of the hill.

Amherst district; Lower Burma.

## Water (see also Engineering and Allied Questions).

Samples obtained from a ten-inch hand-boring made by the North-Western Railway at Rahim-ki-Bazar, about 33 miles south-east of Badin, Sind, and on the northern side of the Rann of Cutch, were forwarded to this department in connection with a water-supply question for the proposed Bombay-Sind Connection Railway.

N.-W. Railway, Rahim-ki-Bazar, Sind; Bombay.

These samples were determined by the Curator, Mr. A. L. Coulson, and consisted mostly of sand and *kankar* to about 265 feet with a conglomeratic band between 227 and 229 feet. Below 265 feet clay predominated, and at the bottom of the boring, 377 feet, solid rock was encountered in the form of a foraminiferal limestone and gypseous *kankar* band.

The limestone contains specimens of the *Globigerinidæ* family, but none of them was sufficiently preserved to be recognised generically. Mr. Coulson remarks that in all probability the limestone is Tertiary in age and might be one of the Tertiary limestones of Sind (Blanford. *Mem. Geol. Surv. Ind.*, XVII, pt. 1, pp. 37-66) or of Cutch (Wynne. *Ibid.*, IX, pt. 1, pp. 74-81). Certain of the limestones of Sind die out to the south-west, near the Habb river (Blanford; *op. cit.*, p. 17), and Wynne states (p. 33) it is quite possible that other east and west dislocations, similar to the great fault along the northern face of the Charwar and Katrol range, Cutch, may have occurred along the northern sides of the Kureer and Bela chain and likewise along portions of the sometimes strongly scarped

hills which rise abruptly from the Rann on the northern margin of Cutch.

Samples of water obtained at various depths in the bore-hole were reported by the Chemical Examiner to the Punjab Government to be unfit for human consumption and for locomotives. The results of the tests are expressed in the following table :—

| | | | | |
|---|---|---|---|---|
| Depth of pipe in bore-hole . | 55′ 8″ | 109′ 3″ | 208′ 7″ | 344′ 5″ |
| Date sample was obtained . | 2-1-1927. | 6-1-1927. | 16-1-1927. | 27-3-1927. |
| Reaction . . . . . | Alkaline. | Alkaline. | Alkaline. | Alkaline. |
| Free carbonic acid . . | Marked. | Marked. | Marked. | Marked. |
| Chloride as NaCl (parts per 100,000). | 2,750 | 5,265 | 23,107 | 21,937 |
| Nitrates . . . . . | *Nil.* | *Nil.* | Present. | *Nil.* |
| Nitrites . . . . . | *Nil.* | *Nil.* | *Nil.* | *Nil.* |
| Sulphuretted Hydrogen . | *Nil.* | *Nil.* | *Nil.* | *Nil.* |
| Lime . . . . . . | Excessive. | Excessive. | Excessive | Excessive. |
| Iron . . . . . . | Traces. | Traces. | Traces. | Traces. |
| Sulphates . . . . . | Excessive. | Excessive. | Excessive. | Excessive. |
| Total solids (parts per 100,000) | 4,281 | 7,310 | 30,730 | Excessive. |
| Hardness (Clarke's Scale) Temporary | 70 | 140 | Excessive. | Excessive. |
| Hardness (Clarke's Scale) Permanent | 420 | 560 | Excessive. | Excessive. |
| Total . . . . | 490 | 700 | Excessive. | Excessive. |
| Free ammonia . . . . | Excessive. | Excessive. | Not estimated. | Not estimated. |
| Albuminoid ammonia . . | Excessive. | Excessive. | Not estimated. | Not estimated. |

A bore sunk to a depth of 850 feet at Drig Road, near Karachi (Crookshank, *Rec. Geol. Surv. Ind.*, LX, pp. 157-169), two bores sunk by the North-Western Railway at Dabheji and Jungshahi in the same district, and a boring made in similar rocks in Kathiawar, all proved these Tertiary rocks to be inpregnated with saline water. It is not therefore considered advisable that the boring at Rahim-ki-Bazar be continued through the limestone in the hope of obtaining a supply of fresh water.

Thayetmyo district: Burma.

In the General Report of the Department for 1926 (*Records*, LX, p. 58) it is mentioned that a report on the waterless tracts of the Allanmyo sub-division in the Thayetmyo district was being prepared by Dr. J. Coggin Brown. It is one of a series dealing with the geology of the waterless areas in the dry zone of Burma generally and the prospects of obtaining underground supplies of water by boring within them.

The difficulties which beset the question have been summarised in the General Report referred to, and it is only necessary to state

here that they are no smaller in the case of the Thayetmyo district than elsewhere.

The Allanmyo sub-division comprises that portion of the Thayetmyo district which lies to the east of the Irrawaddy river. It is divided into the two townships of Sinbaungwe and Allanmyo. In the former there are three waterless tracts and in the latter nine.

*Sinbaungwe Township.*—

*Tract No. 1.*—Tract No. 1 contains the villages, Kyauksauksan with a population of 1,200 souls, Daukhla village, population 80 souls, and Kyaukpyudaung, population 280 souls. These villages lie between 450 and 570 feet, respectively, above sea-level and between five and eight miles directly east of the Irrawaddy, about latitude 19° 45′, in sheet No. 85 M/2 of the one-inch-to-one mile survey of Burma. They all possess tanks which dry up for three months during the hot weather, when water has to be carried from streams one to two miles away. According to the geological map made by Rao Bahadur Sethu Rama Rau in the years 1914-15, the three villages lie on Irrawadian rocks which occupy a wide area hereabouts. There is nothing exceptional in the local structures to lead one to suppose that the possibilities of obtaining underground water at Kyauksauksan or Daukhla are otherwise than doubtful. In the case of Kyaukpyudaung, conditions are perhaps a little better, for rocks of Pegu age, which underlie the Irrawadian series are found one mile to the east of this place. At the same time boring here cannot but be regarded as risky.

*Tract No. 2.* Tract No. 2 lies seven miles to the south-east of Kyauksauksan. It contains the villages of Pozut and Pokolon with populations of 280 and 400 souls, respectively. They both possess tanks which dry up in March, when water has to be carried from the Yebon stream three miles away. The local rocks belong to the Irrawadian and boring is not recommended.

*Tract No. 3.*—Tract No. 3 contains the village of Thittabwe, population 120. It lies in the extreme south-eastern corner of sheet No. 85 M/6 and has an elevation of over 600 feet above sea-level. It is situated between the axes of two well-marked folds in the Pegu rocks but it is doubtful if the expenditure involved in sinking a tube well here is justified for such a small area. The best situation for an experimental test lies on or about the synclinal axis to the north-west of the village, as far as can be judged without an examination of the ground.

*Allanmyo Township.*—

Of the nine waterless tracts in the Allanmyo township, only two have been considered, as the remainder lie outside the area which has been surveyed on the scale of one-inch-to-one-mile, by the officers of the Geological Survey of India.

*Tract No. 1.*—Tract No. 1 is a small area containing the single village of Gwegon, population 600, four miles to the north of Allanmyo. It is located near the junction of the alluvial deposits of the Kyeni Chaung with the Irrawadian rocks and Dr. Brown advocates a search for shallow water in the alluvium to the south of the village, rather than by boring in the Irrawadian.

*Tract No. 2.*—Tract No. 2 includes the villages of Thanat, population 216, Pokolon 315, Yebaw 240 and Sangale 360. All these villages suffer from water shortage in the hot weather, when supplies for human beings are obtained from holes in stream-beds and cattle are driven to the Irrawaddy river some miles away. Thanat, the most northerly village, lies four miles east of Allanmyo. Sangale, at the other end of the tract, is approximately five miles to the south-south-east of Allanmyo. With the exception of Thanat, which lies on Pegu rocks, the other places are all situated on the band of Irrawadian rocks which rises to the east of the narrow belt of alluvium deposited by the Irrawaddy river around Allanmyo and Ywataung.

In Thanat and Pokolon, additional surface supplies from shallow wells may be obtainable. About Sangale, and perhaps between it and Yebok, the question of tapping the "water table" of the Irrawaddy river by means of deep boring arises, but as there is practically no knowledge available as the result of experience on this subject, such borings in these locations could only be regarded as experimental.

Turning now to that portion of the Thayetmyo district which lies west of the Irrawaddy river, waterless tracts occur in the townships of Minhla, Mindon, Thayetmyo and Kama.

*Minhla Township.*—

*Tract No. 1.*—Lebingyin, population 148, possesses a tank which dries up in hot seasons, when water is brought from Paikthin in the Minbu district, four miles away. It is situated in the broad expanse of Irrawadian strata which occurs on the western flanks of the Minbu anticline. Possibilities of obtaining suitable underground supplies at reasonable depths in this situation are remote.

*Tract No. 2.*—Nyaungbingyin, population 220, is said to obtain water from the Irrawaddy, three miles away during the hot weather. This place is presumed to be identical with the Shaukpyingyin on sheet No. 157 of the one-inch map. If this be correct, it lies on rocks of Pegu age which dip to the north-east and possibilities here are not much better than in the previous instance. It is a case where an examination of the ground in detail is necessary before coming to any decision.

*Tract No. 3.*—Tract No. 3 contains the villages of Kanni, population 400, Kandok 520, Sinmagyat 255 and Didokkan 200. The first three have no wells and in the hot weather water is obtained from tanks up to four miles away. Didokkan alone has a tank and a well, and when these fail, water is obtained from a stream two miles away. Kanni lies at an elevation of 1,004 feet on a ridge which forms the water-parting between two well-marked drainage systems. The local rocks have been mapped as the Tabyin-Laungshe group, which is pre-eminently a shaly and clayey horizon. Dr. Brown considers that there are no prospects of underground water at Kanni.

Kandok is on rocks belonging to the Yaw-Pondaung group with a high dip to the north-east. The geological situation at 1,081 feet on a well defined water-parting is bad. Judging from the map alone Dr. Brown does not recommend boring here.

Sinmagyat is five miles east-south-east of Kandok and is situated on rocks of Pegu age, as is Didokkan, a further five miles away in the same general direction. Both villages lie at approximately 1,000 feet above sea-level near the head of a watershed. A simpler remedy than hazarding boring operations in cases like these would be the construction of tanks to be fed by rain.

*Mindon Township.*—

The Mindon town-ship contains five waterless tracts :—

*Tract No. 1*—lying outside the areas which have been geologically surveyed.

*Tract No. 2*—containing the following villages :—

(1) Kyaukpyok, population 140, with one well which is supplemented by water from the Inma Chaung, two miles away ;

(2) Hmoktalon, population 98, with one well supplemented in the same way ;

(3) Inbyit, population 331, obtaining its water in the dry weather from a stream one mile away ;

(4) Yegyansin, population 45, with one tank supplemented by water from a stream one mile away.

The area enclosing these villages is to be found on sheet No. 115 of the one-inch-to-one-mile survey. It was mapped in 1922-23 by Mr. E. L. G. Clegg and is covered entirely by rocks which he grouped together as the Yaw-Pondaungs, of Upper Eocene age. According to him an alternating sandstone shale facies prevails in the uppermost beds and a sandy one below. The main range of which the area forms part is said to possess a general anticlinal structure but it is complicated by strike faulting. Mr. Clegg stresses the high degree of lateral variation which has taken place in the rocks hereabouts, and in the circumstances it is not possible to generalise on the possibility of obtaining water in these localities. A detailed examination of any proposed site is essential before a definite opinion can be given.

*Tract No. 3.*—Tract No. 3 lies in an area which has not been geologically surveyed and the same remarks apply to Tract No. 4.

*Tract No. 4.*—(See preceding sentence.)

*Thayetmyo District.*—

There are four waterless tracts in the Thayetmyo township. As they are nearly contiguous and all lie on a widespread area of Pegu rocks they are taken together. The affected villages are enumerated below:—

| Tract. | Village. | Population. | Remarks. |
|---|---|---|---|
| 1 | Konniywa . . . . . | 350 | No well or tank. Water obtained from wells dug in the stream bed. Supply scanty. |
| | Kyaukme . . . . | 200 | Ditto. ditto. |
| | Tayon . . . . . . | 150 | No well or tank. Water obtained from Inle Chaung one mile away. |
| 2 | Pyaukpyu . . . . . | 200 | No well. Inadequate tank. Drinking water from a well in the stream bed. Other water from Thazi, 1½ miles away. |
| | Akyisa . . . . . . | 200 | No well or tank. Water from the Ponchaung. |
| 3 | Okpon . . . . . . | 200 | No well or tank. Nearest supply at other villages, 2 miles away. |
| | Sanmagyi . . . . . | 210 | No well or tank. Supply from holes dug in the stream bed. |

| Tract. | Village. | Population. | Remarks. |
|---|---|---|---|
| 4 | Taungmyit . . . . | 210 | No well or tank. Water from holes in the stream bed. Supply scanty and poor. |
| | Shanywagyaw . . . | 150 | No well or tank. Poor drinking water from the bed of the stream. Animals watered at Pani Chaung, 4 miles away. |

Tract No. 1 and part of No. 2 lie on the south-west corner of sheet No. 158, and the other two tracts in the western part of sheet No. 159, of the one-inch-to-one-mile survey. The last geologist to report on the area was Mr. E. L. G. Clegg in seasons 1923-24. In sheet No. 158 the two areas concerned lie on the middle sandstone and lower shale divisions of the Pegu group, which are broken up in many places with small faults. Konniywa has an elevation of 421 feet above sea-level but south and east of it is a ridge rising to heights of from 1,300 feet to 1,700 feet. Alternating strata of shales, sandy shales, sandstones and calcareous bands appear to form the ridge. Around Kyaukme is a thick series of shales overlain by sandstone to the west and south-west, which after being folded into a syncline down which the Thazi Chaung flows, rises up to form the outer band of sandstones of the well-known Monatkon dome, lying in the extreme south-western corner of the sheet. The shales in the centre of the Monatkon dome were also found by Mr. Clegg one-and-a-half mile west of Wunledaung, which brings them to about the same distance south of Kyaukme. It is possible, owing to this alteration of sandy and shaly beds, that a favourable site might be found for a deep tube well in the syncline towards the Thazi Chaung, but no guarantee can be given that the water which might be met with would be good, in view of the common occurrence of soluble alkaline salts in the Pegu rocks generally.

The structure near Pyaukpyu is not so satisfactory.

The conditions which bear on this enquiry on sheet No. 159 to the south, are, first of all, the predominantly shaly character of the Pegu beds in the Kadetpyin-Sanmagyi-Myinba valley; these become sandy in the uppermost layers immediately underlying the Irrawadian sandstone to the east, while the high ground around the valley

is formed by intercalations of sandstone. West of this valley is the Okpon dome. The outer band of sandstones on which Okpon itself stands, is overlain by the shales of the Punchaung valley. Neither Okpon nor Sanmagyi are suitably located for deep water tests. The same remarks apply to the villages of Taungmyit and Shanywagyaw which lie on Pegu rocks dipping to the south and close to the overlapping boundary of the Irrawadian.

*Kama Township.*—

The Kama township, Dr. Brown reports, has three waterless tracts. The first of these lies in a geologically unsurveyed portion on sheet No. 116.

Tract No. 2 is a small area containing only one village, Kywetnwe, with a population of 100 souls. It is 5½ miles west of Kama on sheet No. 160, has neither wells nor tanks and obtains its water supplies from the Made Chaung, one mile away. It is situated on the junction of Pegu rocks with the alluvial deposits of the Made Chaung. If the alluvium be thick enough a shallow tube well might yield a good supply of water, otherwise trials might be made by shallow, hand-dug wells.

Tract No. 3 is a large area stretching along the right bank of the Irrawaddy for approximately eight miles in sheet No. 161. It was geologically surveyed some years ago by Dr. Murray Stuart, whose map shows that it is entirely occupied by Kama clays—a division of the Pegu group. As its name indicates, this series is essentially a clayey one though it does contain sandstone bands in places; the latter are not defined separately on Dr. Stuart's map, nor are dips of the strata recorded. For these reasons it is impossible to come to any definite conclusions regarding the possibility of underground water in the tract. On general grounds Dr. Brown considers it an unpromising one.

The affected villages are listed below:—

| Village. | Population. | Remarks. |
|---|---|---|
| Onhne . . . . . . | 85 | No well or tank. Water from the stream. Distance one mile |
| Dangaing . . . . . . | 142 | One well at the *pongyi-kyaung*; supplemented by water from the Irrawaddy river. Distance five miles. |

| Village. | Population. | Remarks. |
|---|---|---|
| Thitmezi | 125 | No well or tank. Water from the Irrawaddy. Distance five miles. |
| Dagon | | |
| Pyaunggya | 135 | Ditto. ditto. |
| Pegya | 196 | |
| Leindon | 229 | |
| Nyaunggaing | 220 | |
| Pebin | 54 | |
| Thetkemyaung | 200 | |

**Waterless tracts of the Kyaukse district, Burma.**

In the Kyaukse district of Burma, nearly the whole of the Myittha Township lying to the west of the Thinbon Chaung and the Samon River, an area of approximately 45 square miles, is classified as a waterless tract. It is found on Survey sheet No. 245 (93 C/7 and C/3) with extensions on to the adjoining sheets to the north and west. For administrative purposes it is divided into the three separate tracts of Hinnyangan, Thittetkon and Yogan.

According to Dr. Coggin Brown's report, the outstanding geological feature of the region is a flat ridge of Upper Tertiary rocks trending from north to south and consisting of conglomerates and gritty sandstones with rare bands of shale. These attain heights of over 600 feet above sea-level and have a high dip to the south-west, two miles west of Gwe.

The possibilities of obtaining good underground water from these Tertiary rocks are remote, but conditions are more favourable on the alluvial areas which surround them and from which they rise; especially is this so in the strip of alluvium forming part of the main Samon belt, on the east of the dry tract.

In the case of the Kyaukse district, unlike others in the "dry zone," the results of an experiment in boring are available. A tube well which was drilled to a depth of 300 feet on a site at Taungdwin, a village on the spread of Upper Tertiary rocks, was a complete failure. When these facts were brought to Dr. Coggin Brown's

attention he suggested another trial at Thittetkon, 3½ miles further east, and within the alluvial area. A successful well was completed here in 1926, which obtains its supply from a bed of coarse sand 75 to 88 feet below surface level.

The Hinnyangan Tract has only one village with 38 households. It lies on alluvium, according to a geological survey by Mr. E. L. G. Clegg (1924-25), and underground supplies should be obtainable, if the alluvial deposits prove thick enough.

The Thittetkon Tract is an important one with 11 villages containing a total of 795 households. The scarcity period when no water exists near the villages lasts from three to four months, when supplies are brought from streams which lie on an average about two miles away. The following villages are within the alluvial area: Pyawywa, Sizongon, Wettein, Tegyi, Thittetkon and Magyigan. Thittetkon now possesses a supply in its tube well and similar underground conditions probably prevail in the others, with the exception of Pyawywa and Sizongon, where they are not so favourable. The remainder are on the Upper Tertiary beds. The largest village of the group, Gwe, with 268 households, is almost on the edge of the Tertiaries and a promising site for a tube well could doubtless be found east of the village and between it and the Samon River.

Dr. Coggin Brown reports that the Yogan Tract has 9 villages containing a total of 138 households, supplied by distant tanks and water holes for three or four months, in years of drought. Borings are not recommended in the cases of Ywatha West, Yogan, Nyaungwin, Yitkan, Thabyetha and Kyadwin. Reconditioning of old tanks and construction of new ones seem to be the only solution of the problem. Nashayo, Letpanbin and Nyaunggyit are on, or near the Thinbon Chaung, which, however, is not a perennial stream. The prospects of a successful tube well, between Nyaunggyit and Nashayo appear to be fairly good.

**Mandalay district: Burma.**

There are three waterless tracts in the Mandalay district; two of these lie in the Singu township of the Madaya sub-division and one in the Patheingyi township of the Amarapura sub-division.

Tract No. 1 of the Singu township has an area of about four square miles with five villages, Kadetchin, Yedwet, Pandin, Tayawpingin and Pinle-in, containing a total of 226 households. The village tanks are dry for four months in seasons of poor rainfall, when water has to be carried from streams from ¼ to 1 mile away.

The group of villages is situated on sheet No. 241 of the one inch-to-one-mile survey, the most northerly being about Latitude 22° 27′ and Longitude 96° 7′. The neighbouring rocks belong to the Mogok gneissose group, which forms an irregular boundary with the alluvium of the Irrawaddy valley. The possibilities of obtaining underground water lie entirely in the alluvium, to the south-west of Kadetchin and to the east of Pinle-in, and if the alluvium is merely a thin skin overlying gneiss, the prospects are poor. If deep alluvial deposits persist up to the gneissic boundary, the prospects are better, but not so good as they are further out into the plain on the west.

The second tract, an area of one or two square miles only, contains one large village, Yenatha, with 250 households. It possesses surface wells and a tank. These are sufficient in years of good rainfall, but in periods of drought, water has to be carried from a stream $4\frac{1}{2}$ miles away.

Yenatha is five miles to the south east of Pinle-in in Tract No. 1 just described. It lies on alluvium with the nearest gneissic outcrop, two miles to the north. Dr. Brown recommends that the surface wells should be deepened if they have not passed through the alluvium and the outer layer of decomposed gneiss. The possibilities of a tube well supply here depend very largely on the thickness of the alluvium.

The waterless tract of the Patheingyi Township covers an area of four or five square miles and contains nine villages with a total of 110 households. They all possess wells which dry up in the hot season, from mid-February to mid-June even if the rainfall is fairly good. At such seasons the villages of Yonbin, Kanbyin and Shwepyi obtain water from a well two miles away and the remainder, Bok, Thetkegyin, Mingan, Zidaw, Sinbut and Yontha, from a spring in Bok Hill at a distance of 4 miles. Bok, the centre of this village group, is eight miles north-east of Mandalay. All the villages are built on a narrow alluvial belt between the isolated gneissic hill of Myotheindantaung on the west and the main outcrop of the Plateau Limestone on the east. It is suspected that the alluvial blanket is thin and that it overlies Plateau Limestone, which would account for its inability to hold water for any length of time.

The alluvial deposits of the valley under Mandalay contain water-bearing sands and gravels and while there would be no objection to trial borings west or south-west of the Myotheindantaung

ridge, no guarantee can be given that borings in the area around Bok, would be successful, owing to the probability of the occurrence of Plateau Limestone at shallow depths below it.

**Sadon Chaung Irrigation Project, Magwe district; Upper Burma.**

At the request of the Public Works Department of the Government of Burma Mr. E. J. Bradshaw was deputed to make a geological examination of the Sadon Chaung Irrigation Project. Preliminary investigations by the Public Works Department showed that the construction of permanent irrigation works on the Sadon Chaung would prove very productive and it was proposed to construct a masonry dam, from thirty to forty feet high, so as to form a tank near the village of Tanaunggwin, which lies on Survey sheet No. 84 P 12 about nine miles north-north-east of the town of Taungdwingyi. The southern part of this sheet, including the reservoir area, was mapped by the late Captain Walker who was killed while working to the west of the area. The mapping of the sheet was completed by Mr. E. L. G. Clegg during the 1925-26 field season and he incorporated Captain Walker's field notes in his progress report for that year.[1]

The beds mapped included Alluvium and rocks of the Irrawadian and Pegu series.

The dam site and the impounding area lie wholly on Irrawadian rocks which were closely examined by Mr. Bradshaw. The Irrawadians lie beneath arenaceous alluvial deposits which are capped by light loamy soil. The alluvium contains a good deal of *kankar* in stringers and nodules and has occasional beds of conglomerate consisting of well-rolled boulders of quartz in a calcareous or ferruginous matrix. The alluvium passes imperceptibly into the upper strata of the Irrawadian series which consists of sandy deposits, false bedded, ill-consolidated and calcareous in the upper horizons. Thin bands of conglomerate, similar to that found in the alluvium, occur sporadically in the upper beds of the Irrawadian. The chief member of the series is a pale green argillaceous sand mottled brown by iron staining. Though this sandy rock weathers like a shale and puddles when mixed with water, it is not impermeable and was soaked with rain water when seen by Mr. Bradshaw. This rock is but partially consolidated and is very friable. It is

[1] See "General Report for 1926," *Rec Geol. Surv. Ind.*, Vol. LX, pp. 83-84.

firm when dug into but rapidly disintegrates and crumbles when exposed to air. This green clay sand is said to be underlain by firm brown clay. At the extreme north-eastern tongue of the reservoir area there are exposures of a compact, gritty "pepper-and-salt" sandstone containing small rounded nodules of grey shale and yellow ochre and alternating with beds of shale. These strata are thought to be of Pegu age by Mr. Bradshaw who remarks that it is difficult to trace a precise boundary as the two series merge into one another. All the strata in the impounding area show strong current-bedding but the general dip is steady and to the south-west.

Trial pits had been sunk at the proposed dam site but at the time of Mr. Bradshaw's visit those in the bed of the stream were filled in and the remaining two were obscured by debris which had fallen into them. These pits showed alluvial soil followed by sand and gravel indicating the past or present bed of the stream, while beneath was green clay sand passing downwards into hard brown clay. The strata attest the rapid lateral variation of the rock series.

In discussing the question of the impermeability or otherwise of the rocks of the dam site Mr. Bradshaw remarks that though there was heavy rain at the time of his visit the flows of the trial pits were dry; he points out, however, that the surface water may have drained out through the debris and through the obviously porous beds which lie above the brown clay. He considers that the soil the sand with gravel, and the clay sand are porous beds and that the clay sand or mixtures of it with the brown clay, might show but little seepage for a certain period but in the course of time might disintegrate and be a source of leakage which could not be adequately compensated by the sealing effect of the disposition of clay in the interstices.

Firm clay, thanks to its impermeability and high bearing strength, is considered to be a good foundation for earthern dams and, though not ideal, a really hard and homogeneous clay may constitute a reasonably secure foundation for a masonry dam if precautions, such as sheet-piling, are taken to prevent the spreading and welling-up which might occur were it not so confined. Mr. Bradshaw points out that the danger with clay foundations is that the bearing strength may prove insufficient for the concentrated stresses of a masonry dam and that in the case under consideration there is the probability of the existence of lenses of ill-consolidated or permeable materials. The occurrence in rivers of firm hard clay unmixed

with sand is comparatively rare. If sand be mixed with the clay the danger of seepage or undermining from above and of erosion on the down-stream side is greatly increased and it may be doubted whether it would be safe to construct a masonry dam on such foundations. Mr. Bradshaw considers that if construction be decided upon the clay at the dam site should be carefully examined with regard to its thickness, texture and homogeneity and that the site should be more thoroughly proved than has yet been done. In view of the unreliable nature of the rocks themselves, the irregular bedding and the rapid lateral variation, it would be essential to dig a trench at least twenty feet deep on the whole length of the dam site to prove the actual presence of the firm brown clay along the whole line, and by drilling in the trench to ascertain whether there is a sufficient thickness of this rock.

Mr. Bradshaw doubts whether the foundations will prove suitable for a masonry structure but considers that it would be possible to construct an earthern dam which would itself be water-tight and stable. He states that there are, unfortunately, other considerations which are, to his mind, of sufficient weight to give reason for the condemnation of the proposed site of the dam and of the whole impounding area. The coincidence in this area of the Pegu-Irrawadian boundary with that of the Government Reserved Forest is due to the porosity of the Irrawadian rocks and, indeed, the dry zone in Burma owes its aridity to the permeability of the series. Irrigation projects in Irrawadian areas must always be examined with care for it is almost a foregone conclusion that there will be leakage. In successful cases the initial leakage decreases in time owing to the deposition of clay in the voids of the porous sands from the muddy impounded water which percolates through them. The Irrawadian are unreliable rocks and forecasts as to their behaviour are hazardous; where, as in the present case, there are, besides the porosity of the rocks, other objections to the choice of any particular locality for an impounding scheme, the possibility of success becomes remote.

The nature of the geological structure constitutes the first of these additional objections. Throughout the impounding area the dip is remarkably steady. At the dam site it is down-stream while along the western margin of the impounding area it is outwards. Such a structure would be undesirable in any area in which it was proposed that water should be impounded. In one where the

majority of the rocks are porous it is probable that the amount of the initial leakage down the beds, and so out of the impounding area would be heavy and Mr. Bradshaw doubts whether it would ever be sufficiently reduced by the sealing effect of the clay carried by the percolating waters. He points out that, speaking generally, in the area under consideration the higher the horizon the greater is the porosity of the rocks. The risk of leakage on account of the structure is greatest along the western margin of the impounding area where the dip is outwards and it is there that the youngest beds are exposed. That these rocks are the most porous is a factor which obviously increases the probability of serious leakage and Mr. Bradshaw remarks that a further unfavourable circumstance is that the impounding of water by a relatively high dam would result in the submergence of still higher, and hence more porous, horizons with a correspondingly increased amount of leakage from the higher levels.

Discussing the topography of the proposed impounding area Mr. Bradshaw notes its deceptive nature and how the actual impounding area would be much smaller than what one would expect at first sight. Above the dam site the stream makes a loop which is almost a complete circle. Due east of the proposed site there is a narrow tongue of high ground composed of loosely consolidated arenaceous deposits with high and exceedingly steep cliffs forming the banks of the stream. The breaching of this tongue of high ground by the ordinary processes of mechanical erosion is but a matter of time, and is taking place with unusual rapidity. The main factor is the undermining of the bank due to the erosion of the stream, especially when it is in spate. This source of erosion would be almost entirely eliminated were the flooded stream to gave place to the still waters of a reservoir. Though under-cutting by the stream itself is the chief, it is not the only factor in the piecemeal erosion of the high ground. Heavy rain fell throughout the period of Mr. Bradshaw's visit and though this resulted in there being water in the bed of the stream, the flow was negligible and erosion from that source was *nil*. At least twenty landslips were counted in the banks of the stream and though most of these were small some were of serious dimensions, the largest being either at the dam site itself or on the further side of the tongue of high ground due east of it. It is evident that the ground in the neighbourhood of the dam site is unstable and that this must be the case is apparent when it is remembered that the high

cliffs, which form the bank of the stream and which in some places approach the vertical, are composed of loose sandy deposits. The high ground above the cliffs constitutes a catchment area from which the surface water runs into the stream in numerous streamlets all of which are cutting back rapidly. The lack of cohesion in the rocks together with the steepness of the cliffs greatly increase the amount of erosion effected by rain alone. If two days' rain can produce a large number of landslips it is clear that the amount of erosion during the wet season will be severe and a serious menace to any structure beneath the cliffs. In Mr. Bradshaw's opinion it is doubtful whether it would be possible to construct a dam which would not be outflanked in the course of time. He considers that both from the engineering and the geological points of view the instability of the cliffs and their liability to erosion constitute a danger which should not be underestimated when assessing the possibilities of the success of the project.

With regard to the supply of building materials, materials suitable for the construction of a masonry dam are available in quantity at the site of the dam. The clay sand and its mixture should be avoided and only the firm brown clay used. Building stone suitable for the construction of a masonry dam does not occur in the immediate neighbourhood of the proposed site but some two miles up-stream along the Sadon Chaung and the Thapain Yoh there are large quantities of sandstone boulders of Pegu age. Cart tracks exist and transport should be neither difficult nor expensive. It is doubtful whether it would be possible to find a sufficiency of solid rock with an open face suitable for quarrying, but the sandstone boulders afford an ample supply of suitable stone. At Htonbo, about two miles from Tanaunggwin, there are old lime quarries. These were not examined by Mr. Bradshaw but he understands that the source of the lime is *kankar* and that the quality is not good.

In condemning this site Mr. Bradshaw considers it unlikely that a suitable alternative one will be found within the Irrawadian area and that such a site, if desired, should be sought for up-stream in the Pegu region. Such a course would increase the difficulties of constructing distribution channels but no alternative seems feasible, except, perhaps, the substitution of a weir with direct irrigation from the stream in place of the dam and reservoir of the present project.

The Public Works Department of the Government of Burma reported that the present Sinbyugyi Tank near Tezu village, about nineteen miles north of Meiktila town. Upper Burma, which stores up the waters of the Mondetyewin Chaung, had accumulated large quantities of silt and its storage capacity had been considerably reduced. The *bunds* of the Sinbyugyi Tank were being raised two feet but, as the silt deposits continue, it was expected that in the near future the maximum flood level would reach the crest level of the embankment. In preference to undertaking extensive repairs to the Sinbyugyi Tank it was proposed to investigate the possibility of rebuilding the ancient Burmese Tagundaung Tank which is at present in disuse, and Mr. E. J. Bradshaw was deputed to report on the geological aspects of the scheme.

**Tagundaing Tank Irrigation Project, Meiktila district; Upper Burma.**

The Tagundaing Tank is supposed to have been constructed during the reign of King Anawrata about three centuries ago. The remains of the old dam are visible in the Mondetyewin Chaung, the feeder of the Sinbyugyi Tank, about two-and-a-half miles south-west of Tezu and take the form of an earthern *bund* about nine hundred feet long and some sixty feet high from the bed of the stream. The Irrigation Engineers consider that this would be the best site for the new dam which would be of masonry or concrete arch type. The catchment area of the Mondetyewin Chaung at the site of the dam is approximately fifty square miles with a probable run-off of about sixty per cent. of the total rainfall. which is about thirty-two inches a year. The available run-off would, therefore be of the order of 4,460 million cubic feet. Rough figures show that the storage capacity for the proposed tank would be about 128 million cubic feet giving an irrigable area of about five thousand acres, or a net increase of about three thousand acres. Streams in this part of Burma are dry for a considerable part of the year but are liable to sudden and heavy spates, usually in the months of June and August. At the end of October there is again a shortage of water. It is proposed that the surplus water from the Tagundaing Tank should be diverted partly into the Mondetyewin Chaung and so into the Sinbyugyi Tank and on the south side into the Natkan Myaung. The first would have the effect of maintaining Sinbyugyi Tank as a subsidiary tank with greatly reduced and moderated floods, and would considerably reduce the volume of silt deposited

in it. The sluice on the south side, running parallel to the Natkan Myaung, would command an area of about four square miles.

The site of the dam and of the impounding area lies within a region of Pegu rocks, on Survey sheet No. 84 O 16 which was mapped by Mr. E. L. G. Clegg during the 1924-25 field season. To the east of the sheet there is a belt of alluvium on which the village of Tezu is situated. To the west of this, running due north and south, there is a ridge of low hills known as the Taungnyo Hill ranges and composed of rocks of the Pegu series. The strata consist of alternating beds of shale and compact, false-bedded sandstones with occasional thin calcareous bands. The structure is a more or less asymmetric anticline with the axis lying a little to the east of the hill range. Small minor faults are common and it is probable that further to the south a fault forms the broken crest of the anticline.

The site of the proposed dam is a breach in the ridge, which here forms a natural embankment west of which the stream runs till it cuts across it at right-angles at the site of the dam. The average dip of the strata is about 35° to the west, or due up-stream at the site of the dam. On the south side of the breach the dip is steady along the line of the *bund* but swings slightly to the south-west at its southern end, flattening for a short distance. Here, about two hundred yards from the breach, there is a small stream which might be adapted to form an escape channel provided the height were suitable. North of the breach Mr. Bradshaw noticed a certain amount of crumpling while some of the strata south of the breach show signs of buckling and have evidently been subjected to considerable stresses. Two small faults were noticed south of the breach, one about 100 yards south-east of it and the other near the small stream referred to above. Both these faults appear to be sealed.

At the dam site itself there is exposed a rather coarse-grained, micaceous, "pepper-and-salt," false-bedded sandstone mottled with reddish brown iron staining. This rock is tough and compact and sufficiently impervious for all practical purposes. Eastwards it becomes rather more argillaceous and friable while the clay partings are more numerous. The sandstone beds average about 18 inches in thickness and have very thin partings of papery shale or very argillaceous sandstone. Occasionally the partings are calcareous. The sandstone and the shale are often ripple-marked and sometimes coated with efflorescent salts. North of the breach the sandstone often contains small nodules of green-grey shale or yellow ochre.

South of the breach the rock is finer in texture and is greenish buff in colour. There are thin partings of very fine-grained, dark shale which also occurs in the rock in the form of small, rounded nodules.

Though the coarse sandstone which occurs at the site of the dam is itself practically impervious, it is freely jointed. The majority of the joint planes are parallel to the bedding planes and so should not greatly affect the tightness of the dam, but those joints which cut across the bedding planes might be a source of leakage at first; the amount would probably diminish in time and the risk is decreased by the fact that in many places the cross-jointing does not intersect the shaly partings at all.

No pits had been dug to prove the strata at the site of the dam nor was any information available as to the extent or shape of the impounding area. In such circumstances it is not possible to give a definite opinion on the suitability of the area for the impounding of water and Mr. Bradshaw considers that his views should be regarded as preliminary rather than final. He states that the sandstone which at the site of the dam is a tough and massive rock may there be considered sufficiently impervious for all practical purposes. The rock sequence itself, consisting, as it does, of an alternation of compact sandstones and thin shale partings, may be pronounced suitable for the retention of water. The geological structure along the line of the *bund* is almost ideal, the strike being parallel to the line of the *bund* and the dip inwards into the reservoir area. For the reasons stated above the impounding area was not examined in detail but the cursory examination made indicated that in all probability it would prove water-tight.

The possibility of the existence of small, concealed faults which might prove a source of leakage is perhaps not serious since it is to be presumed that the reservoir has been successfully used for the impounding of water in the past. A more serious possibility is that the breach in the ridge through which the stream runs may be due to the presence of a fault plane. The fault, if it exist, is at present concealed by the alluvium but the buckling of the strata in the vicinity of the breach and the existence of the breach itself, make the presence of such a fault a possibility on which no definite opinion can be given until the site is proved by digging. The fact that while solid rock is exposed on the left bank at the breach there is no exposure of any rock other than alluvium for some 100 yards to the south of it, is probably due to the widening of the

breach by erosion of the left bank on account of the right-handed turn made by the stream.

It is recommended that trial pits or, better, a deep trench, should be dug along the line of the proposed dam site to prove the presence or otherwise of continuous solid rock suitable for the foundations of a dam. For the greater part of the length of the proposed *bund* the work would merely consist of the raising of the present level by a few feet. Good alluvial earth is available close to the reservoir area and there is an abundance of good sandstone at the site of the dam itself. The most suitable is, in Mr. Bradshaw's opinion, the tough, compact rock which occurs at the dam site and which should be used in preference to the more argillaceous and friable types which are found east and south of the breach. The sandstone is freely jointed and easy to work.

Mr. Bradshaw suggests that should it be decided to construct an earthern dam it might be advisable to build one with a core wall because of the difficulty of bonding earthwork with the solid rock which occurs north of the breach. He also notes that it is where the present breach in the ridge exists that the embankment will be wholly artificial, and suggests that it might be advisable to cut the escape or overflow channels elsewhere rather than at this point.

**Jhansi water-supply United Provinces.**

At the close of his field season in Sirohi State, Rajputana, Mr. A. L. Coulson proceeded to Jhansi in order to examine a well concerning which certain questions had been asked by the Garrison Engineer, Jhansi. A newer and a larger scheme for supplying water to the whole of Jhansi Cantonment having been sanctioned meanwhile by the military authorities, the well in question was required to provide only a temporary supply of 80,000 gallons of water daily.

As Jhansi is situated upon a tract of gneissose granite with small stretches of alluvium bordering the rivers, and as this granite is not water-bearing except in the upper decomposed portions, there is no hope of obtaining artesian water by boring in the granites.

On account of the special local conditions prevailing, the area tapped by the well in question may be considered potentially as the elongated mass of alluvium of variable depth and width, stretching upstream from the well. Near the well, there is a natural underground dam of fresh granite and so the feeding effect of the downstream alluvium may be neglected. In order to augment the

supply of water, the well, which is connected to a smaller and deeper well, could be deepened. As an alternative a stone gallery could be constructed from the smaller adjacent well stretching upstream between the larger well, and the fresh granite cropping out on the far side of the Baberi river. This latter method would be less costly but would not have the advantage of increasing the actual storage capacity of the large well by 120,000 gallons (from 160,000 to 280,000 gallons) which would be the result of deepening the larger well by 10 feet, its diameter being 50 feet.

With the oncoming of the hot weather and the continual removal of water from the natural underground reservoir, the water-level drops and, as Mr. Coulson remarks, such a drop might be sufficient to isolate the potential reservoir into a number of smaller disconnected ones. The annual rainfall of Jhansi and its district is about 38·5 inches but, assuming a minimum annual fall of 15 inches and a drainage area affecting the well of 2 square miles, the minimum amount of water falling annually to replenish the reservoir is about 435,000,000 gallons; if but $\frac{1}{6}$th of this were available after run-off and evaporation, it would be sufficient to provide 200,000 gallons of water daily provided it were ideally available throughout the whole year. Actually, only 30,000,000 gallons are required annually and in the monsoon the 7,500,000 gallons pumped may be considered as being obtained from the run-off portion of the annual fall, thus leaving but 22,500,000 gallons to be obtained from the natural reservoir during the remaining 9 months. An actual working test alone will tell whether this will be available but, as calculated above, the fall is ample to replenish the reservoir by more than this amount.

A previous test showed 150,000 gallons of water *per diem* in the hot weather but the test was carried out after a heavy thunderstorm and the water was not taken sufficiently far downstream to ensure that it did not percolate back to the well. A new test was to be made and if the supply of 80,000 gallons were maintained, then the probabilities of it being available throughout the whole year would be good at the same time. It must be remembered that such a test does not repeat actual working conditions inasmuch for the months following the monsoon, the supply has not been drawn upon to the extent of 80,000 gallons daily.

According to Mr. Coulson there are abundant natural subterranean dams throughout the cantonment area along the courses of the Baberi and Dhobi rivers; the latter is better provided with

water storing alluvium but its drainage area is chiefly the cantonment itself and for reasons of purity of supply, the Baberi river is to be preferred. Should any large supply be required, either a series of wells would have to be sunk or else a supply obtained from a more favourable source without the cantonment limits.

## GEOLOGICAL SURVEYS.

Assam.

Whilst examining the sillimanite-corundum deposits in the neighbourhood of Sonar Pahar (near Nongmaweit village), Nongstoin State, Khasi Hills, Assam, Dr. J. A. Dunn made some notes upon the geology of the Khasi Hills plateau. From the Brahmaputra plains southwards the greater part of the plateau is seen to consist of a granitic rock, often gneissic in texture. It varies from a fine-grained rock frequently finely banded, to a coarse porphyritic rock, which also usually shows a certain amount of banding. In colour the rock varies from white to red. So far as could be determined, this granitic rock is intrusive into all the other metamorphic rocks - mainly hornblende schists and mica-schists passed over on the march.

In the vicinity of Sona Pahar the dominating metamorphic rock is a sillimanite cordierite biotite-quartz-microcline-gneiss with which is interbanded a sillimanite-quartz-schist. An additional rock-type is an orthorhombic pyroxene-diopside-felspar rock. There has apparently been a considerable amount of folding, but the general strike of the rocks is east and west.

The origin of the cordierite-bearing gneiss and the sillimanite-quartz-schist is not clear. There is no doubt, however, according to Dr. Dunn, that they are interbedded and the simplest suggestion would be that they form a succession of highly aluminous sedimentary beds, the sillimanite-quartz-schist representing an extremely pure variety of clay. It is within this aluminous series that the sillimanite-corundum deposits are found.

The bottoms of the wide valleys are usually covered with a thick peat deposit.

**Bihar and Orissa. (Bonai and Keonjhar States).**

During the field season 1926-27, the Bihar and Orissa party consisted of Mr. H. Cecil Jones (in charge), Dr. M. S. Krishnan and Sub-Assistant L. A. Narayana Iyer.

Mr. Jones continued the systematic geological survey of the iron ore area in the Feudatory States of Bonai and Keonjhar, and worked on the Bihar and Orissa standard sheets Nos. 73 G/1 and G/5. The geology of the area worked over is very similar to that gone over last season. The Iron Ore series occupies most of it. Good sections through the iron ore range are not often seen, but the Samaj stream breaks through the range near Toda (21° 59′: 85° 11′) and, about 12 miles farther to the south, near Dumaro (21° 50′: 85° 07′), the Kurhadi stream breaks through, and at each of these points are excellent sections through the range. In the former case, the banded hæmatite quartzite which forms the backbone of the range seems to be very folded and is generally bent into a steep anticlinorium, whilst in the latter case the bedding, which strikes N.N.E.- S.S.W. and dips about 70° to the W.N.W., appears very regular; although folding and faulting are fairly common, these do not seem to affect the general strike and dip of the rocks. In the Kurhadi stream gorge there is a thickness of about 2,500 feet of the banded hæmatite quartzite exposed. At the west end of the gorge the quartzite is overlain by thick flows of basic igneous rock (mainly epidiorite), which in places has penetrated along the bedding planes and cracks in the upper beds of the quartzite, but seems to have had little effect on it. The country at the east end of the gorge is largely covered, and the rocks underlying the quartzite are mainly shales.

An interesting occurrence of volcanic ash, in which are numerous well rounded volcanic bombs, was noted in the above mentioned basic igneous rock. The ash bed is exposed in the Kurhadi stream-course near Dadan Raikela (21° 53′: 85° 06′) as a fine-grained greenish-grey somewhat schistose-looking rock, in which a number of well rounded and sometimes angular boulders up to a foot or more in diameter. occur. The rock forming these rounded masses is a rather hard. fine-grained compact epidiorite, and has quite a different appearance from that of the ash in which it has been embedded. It sometimes contains areas of white quartz which were probably steam holes when the rock was in a molten condition.

The conglomeratic sandstones noted by Mr. Jones last season were found to extend only a very short distance to the south before the granite appeared. The small exposure of these sandstones in the area gone over did not give sufficient evidence to decide their age.

In the extreme south of the area worked, the banded hæmatite quartzite and shales of the Iron Ore series appear to be bent into a north-easterly pitching overfolded synclinorum, the western arm forming the main iron ore range, the rocks of which strike roughly N.-S. or N.N.E.-S.S.W., with a dip of about 70° in a direction W. or W.N.W. The eastern arm strikes roughly N.E.-S.W. with a dip of about 30 to 40° to the N.W. Although there are considerable quantities of good hæmatite in the eastern arm area, the replacement appears to be not nearly as extensive or complete as in the western arm.

Inspections.

Mr. Jones paid two visits to the prospecting work being carried out by the Tata Iron and Steel Co. at their Noamundi iron mines in the Singhbhum district. Mining work has been started on a fairly large scale and the output when the mine was visited in early April 1927, was about 1,500 tons daily. This mining work has proved that some of the shaly ore can be used in the blast furnaces. This shaly ore is often rather friable and there is a considerable amount of waste of fines during mining, transport, etc. The prospecting work has also shown that the area is very broken up by faults, so that a larger number of prospecting pits and borings would be necessary to obtain anything like a reliable estimate of the quantities of iron ore on the property.

The geological mapping of Keonjhar State, Bihar and Orissa, which was commenced in the last field-season, was continued by Dr. M. S. Krishnan during 1926-27. The area mapped lies in Survey sheets 73 F/12, G/5, G/9, G/10 (1 inch=1 mile).

The geological sequence in this part of the country is the same as that given for the adjoining region in the General Report for the last season (*Rec., Geol. Surv. Ind.*, LX., p. 77). The oldest rocks, which are of older Dharwar age, are confined practically to sheet 73 F/12, except for a small area to the west of Kondraposi (21° 48′ 30″; 85° 31′) in sheets 73 G/5 and G/9. A number of irregular inclusions are also found amidst the granites. They consist of hornblende and mica schists, and quartzites; these last show signs of crushing, the fragments having been re-cemented by secondary silica. Microscopically they are seen to consist of quartz grains with sericite as the cementing medium.

Veins of quartz sometimes traverse the planes of schistosity in the schists, and seem to belong to the period of granitic intrusions

since they are free from the effects of pressure prominent in the schists. The usual direction of strike is N.-S., or between this and N.N.W.-S.S.E.; the dip is always high, and frequently vertical.

The Iron Ore series, composed of sandstones, shales, banded hæmatite quartzites, and shales, in ascending order, occupy the whole of sheet 73 G/5 and the adjoining western edge of sheet 73 G/9. The lowermost beds are sandstones, with bands of quartzites and conglomerates. These dip at 15° to 25° in a direction which varies between W.15°N. and W.15°S. The conglomerates contain pebbles of quartz and jasper; the latter are not found as constituents of the older Dharwars in this area, and hence may either have come from a distance, or have been derived from beds which have since disappeared through denudation.

Field evidence shows the existence of two series of shales, one above, and the other below, the banded hæmatite quartzite. Owing to their lithological similarity, distinction between the two shales is difficult. There is probably a slight unconformity between the lower shales and sandstones. The shales strike, on an average, in a N.E.-S.W. direction, the dips being fairly high. The alteration of shales to laterite is a wide-spread phenomenon. At some localities, more favourable conditions have given rise to pockety segregations of iron and manganese ores (limonite, hæmatite, pyrolusite, wad, psilomelane, etc.).

The banded hæmatite quartzites are conformable to the shales. They are composed of alternating bands of hæmatite and quartz, the average thickness of single bands being about 1/10th inch. The rocks are considerably folded with a dip in a N.W. to W.N.W. direction at usually 30° to 60°.

Parts of the area, particularly the hills composed of banded hæmatite quartzite, are capped by iron ore which is a product of metasomatic replacement of quartz layers by the ferric hydrate carried down by percolating waters. The presence of organic acids derived from decaying vegetation and a fluctuating water-table, should have facilitated the replacement. The quartz leached away during the process of replacement is frequently seen at the foot of the hills, or in the immediate neighbourhood.

The granites are intrusive into and younger than the above-mentioned formations, and occupy nearly the whole of sheet 73 G/9, and the part so far mapped in G/10. They generally bear microcline, and are poor in ferro-magnesian minerals. Veins of

quartz and pegmatite seem to be common but Dr. Krishnan has, so far, come across none of the minerals associated with large masses of granite. This points to the complete absence of any mineralising influences.

A granite-porphyry occurs in an exposure near Nardupur (21° 59′ 30″; 85° 33′).

Belonging to the same granitic suite, is a dyke of rather peculiar sub-acid composition, stretching from Sosang (22° 1′; 85° 40′, in sheet F/12), to near Khuntapoda (21° 52′; 85° 36′ 30″, in sheet G/9). The specimens collected from this dyke show types varying from almost pure micro-pegmatite (sp. 36/502; slide 17,468) to augite-diorite with interstitial micro-pegmatite (sp. 36/516; slide 17,480, etc.). Most of these show a fair amount of greenish epidote.

The youngest of the formations are basic igneous rocks, seen mostly as dykes in the granite region and as sills in the Iron Ore series. The majority of the dykes trend conspicuously in a N.30°E.—S.30°W. direction, which corresponds, in some parts at least, to the direction of one set of joints in the granite.

The petrographic types include gabbros, dolerites and basalts; they are devoid of olivine and rhombic pyroxene, but enstatite-augite is sometimes, and interstitial micropegmatite almost always, present. This last characteristic may either be due to the absorption of siliceous material from the granite, or may be a peculiarity of the basic magma itself. There is a great deal of similarity between these and the trap dykes of Cuddapah age in the Madras Presidency, and the dykes in the Bijawars and Gwaliors (*see* Sir T. H. Holland; *Rec., Geol. Surv. Ind.*, XXX., pp. 31-37) which suggests that all these may have a community of origin.

During the field-season, 1926-27, Sub-Assistant L. A. Narayana Iyer was engaged in the geological survey of the Kolhan Government Estate, Bihar and Orissa, on standard sheets 73 F/3, F/7, F/11 and F/16. Sheets F/11 and F/16 have now been completed.

Rocks met with included the older metamorphics as inclusions in the Singhbhum granite, the Iron Ore series including the acid and basic volcanic rocks, and the newer dolerite.

The rocks of the Iron Ore series in sheets F/3, F/7 and F/11 are described as consisting mostly of shales, which show little evidence of metamorphism, and in some places even no cleavage, but are massive and earthy. These shales often pass into a white clay or

kaolin, of which some of the hills are made up. In one place this clay was worked for some time for kaolin. The shale is sometimes sandy, sometimes silicified and often passes into the dark carbonaceous shale. There are also thin bands of interbedded sandstones in the shale, and these sometimes form bold ridges. The shale varies from an earthy brown colour to almost a pure white.

The igneous rocks of the area are both acid and basic. In the white shale on some of the hills occurs a gritty rock, which on examination is seen to be either an altered acid volcanic tuff or a sheared quartz porphyry. The latter is a devitrified ancient lava. The ground-fabric of the acid rocks is so similar to the shales, that some at least of the latter may have been derived from these volcanic rocks. Similarly some of the darker shales are derived from the weathering of the dolerites.

In sheet F/7, the basic volcanic flows or sills are found to a greater extent than in sheet F/11. They have been found in the north-east corner of the sheet, in the central portion and west of Sangajata. The first mentioned are in continuation of, and more or less in the same strike with the Saidba volcanic flows mapped by Dr. Dunn in sheets, F/6, F/10 and F/14. A larger development of the basic flow is seen round Kendbai in the Leda Reserved Forest; here the flow consists of numerous bands of dolerite with intervening shale (at times carbonaceous) extending from the neighbourhood of Kendbai W.S.W. towards the Karo River. There are also further bands south of this area running west of the main ridge, Patum Buru, and also thin bands running along it on its eastern flank. Some of these bands west of the main ridge cross the Karo and are found in the hills of the Ambia Reserved Forest. The dolerite in the areas is somewhat altered; the pyroxene has been changed to chlorite, the plagioclase to sericite and saussurite liberating quartz, while the ilmenite has all been changed to leucoxene.

Mr. Iyer puts forward the view that south Singhbhum was an area of volcanic activity as well as north Singhbhum, but that the basic sills and flows do not cover such large areas as in north Singhbhum. An additional interest lies in the presence of acid volcanic rocks in close proximity to basic while the rocks of north Singhbhum show all stages of metamorphism; their supposed equivalents in south Singhbhum have undergone little change.

Whilst investigating deposits of kyanite in this Province, Dr. Dunn made a traverse through Kharsawan and Seraikela States and the Dhalbhum sub-division of the Singhbhum district.

**Bihar and Orissa.**

During this traverse he noted that the beds in north Singhbhum which he has classified as the equivalents of the Iron Ore series continue south-east into Dhalbhum and carry the same metamorphic facies. From the general east-west strike of the rocks in north Singhbhum there is a gradual swinging of the strike to the south-east so that ultimately in the south-east of the area the strike becomes south-south-east, continuing into Mayurbhanj State.

Dr. Dunn examined the kyanite deposits of Barabhum in the Manbhum district, and is of opinion that the contact between the Chota Nagpur granite-gneiss and the Iron Ore series is not a fault junction, as indicated on the old maps, but a natural intrusive contact. There is, however, apparently an impersistent line of fault some distance to the south of the boundary of the granite-gneiss.

During the field season 1926-27 the Burma Party consisted of Dr. J. Coggin Brown (in charge), Messrs. E. J. Bradshaw, C. T. Barber, P. Leicester, V. P. Sondhi and B. B. Gupta.

**Burma Party.**

Mr. E. J. Bradshaw resumed the survey of the Sagaing district but contracted malaria and enteric and had to close camp after a week's work on sheet 84 N/16. At the south-eastern margin of the sheet a ridge of Archæan rocks runs due north and south on the right bank of the River Irrawaddy and consists of gneiss with schist and bands of crystalline limestone on its western flank or forming minor hills west of the ridge. The limestone varies from a bluish-grey, laminated rock to a pinkish white marble, usually in thin, discontinuous bands, and is closely folded. The cleavage planes were observed to dip at about 30° towards the east; the bedding is parallel to the foliation planes of the gneiss and usually approaches the vertical, but flattens eastwards to about 45°.

**Sagaing district, Upper Burma.**

Three miles east of Padu the limestone occurs as bands in a weathered, greenish, biotite schist with the biotite passing into chlorite. The rock in the main ridge is fresher, the predominating types being a pale-grey or white, finely-banded gneiss composed mainly of quartz and felspar with a subsidiary ferro-magnesian

mineral which is usually biotite but sometimes hornblende. White quartz is copiously injected as veins and stringers into all the Archæan rocks. The schist often weathers like a shale, breaking into small iron-stained discs and decomposing into a pale green, calcareous clay.

On the western flanks of the ridge there is a considerable amount of debris which sometimes takes the form of a boulder bed with boulders of quartz or of the various types of gneiss in a matrix of calcareous quartz gravel, the included boulders being angular, sub-angular, or rounded. Eastwards this deposit passes downwards into weathered gneiss *in situ*, and westwards into the quartz gravel which underlies the dark soil-cap of the low ground. This quartz gravel is similar to the matrix of the boulder bed and consists of a calcareous grit or gravel with small, usually unrounded, pebbles and boulders of quartz, gneiss or limestone. Though false-bedding was noticed in places the rock is more or less incoherent. The general dip is uncertain but is probably low and towards the W.N.W. The size of the pebbles increases steadily as the ridge is approached until the deposit merges into the low scree of debris from the ridge. The determination of the age of this deposit requires further field work. Though no fossil wood was noticed and though the deposit has clearly been derived locally rather than transported, it will probably prove to be Plateau Gravel rather than Older Alluvium.

In the hills between Saye and Ondaw the calcareous quartz sand or gravel is underlain by a Tertiary series of thin beds of sandstone with intercalated, crumbling, calcareous shales in beds a few inches thick. The sandstone is usually fawn in colour, and friable. It is sometimes compact, ferruginous, and laminated, sometimes incoherent and coated with efflorescent salts. Springs are common but the water is usually saline. The hills are low and undulating with the dip and strike of the rocks very variable. A small fault was noticed on the road from Saye to Yemyet. As no fossils of any kind were found, further field work will be necessary before it will be possible to subdivide these Tertiary rocks into Pegus and Irrawadians.

**Amherst district, Burma.**

Before his deputation to the Toungoo and Salween districts Mr. P. Leicester worked in the Amherst district for a short time and mapped part of sheets 95 E/10 and E/13 and completed sheet E/9.

The granite, which occurs along the coast in sheets 94 H/12 and 95 E/9, is continued southwards into sheet 95 E/10, forming the low hills of Takalwin Taung (97° 42′ 40″; 15° 45′ 0″) and Thabut Taung (97° 42′ 45″; 15° 42′ 0″) situated to the west of Tinyu.

Both Thabut Taung and Takalwin Taung are composed of biotite-granite. Takalwin Taung slopes steeply to the sea on the west and on the sea shore there are excellent exposures of distinctly banded biotite-granite, with xenoliths of dark hornblende granulite like that found at Amherst and in the other granite occurrences along the coast in sheet 95 E/9. The xenoliths, some of which are considerably twisted, are drawn out in a direction N. 45° W. Both the granite and the xenoliths are cut by later veins of porphyritic granite.

Thabut Taung is separated from the sea by a narrow band of alluvium and a sandy shore. The granite, a biotite-granite, exhibits remarkably good jointing resulting in the formation of tabular blocks and the ground around the hill is strewn with granite boulders. The eastern slopes of both hills are covered with laterite near the foot and beyond the edge of the laterite is a fertile band of alluvium, a continuation of the alluvium found to the north, stretching to the railway on the east.

The westerly dipping sandstones and shales of the hills on the coast near Amherst appear to be represented by the sedimentary rocks which form Mawpalaw Taung (sheet 95 E/13. 97° 46′; 15° 52′). This hill is situated east of Karopi and forms a short ridge, with a direction N.N.W.–S.S.E., around which tin mining is being carried on on a small scale. The hill is composed of red, buff and white sandstone and banded quartzite associated with shales and dark micaceous slate. The whole is cut by quartz veins and stringers which presumably carried the tin found in the laterite at the foot of the hill. The strike of the sandstones is N. 25° W., with a dip of 45° to the west.

The tin ore which is recovered from the laterite at the foot of Mawpalaw Taung by sluicing during the rains and by panning, is grey cassiterite with a little black cassiterite. The ore appears to be derived from small cassiterite-bearing quartz stringers intruded into the sandstones during the period of granitic intrusion of the province. The tin has been concentrated in the alluvium of the hill-sides and now appears scattered through the laterite deposits in the vicinity.

Mr. P. Leicester, in the course of the work of the Rangoon Water-Supply and Hydro-Electric Survey Party, mapped parts of sheets 94 B/16, 94 F/3 and 94 F/4 in the Toungoo and Salween districts. The geology of this area has already been referred to under the Rangoon Hydro-Electric and Water-Supply Survey on page 29.

Toungoo and Salween districts, Burma.

The fine-grained granite mentioned on page 31, when examined under the microscope, proved to be a soda-granite with quartz, dominant idiomorphic albite and subsidiary allotriomorphic orthoclase and large well preserved laths of brown biotite.

The medium-grained granite shows quartz with dominant orthoclase, perthite, albite, biotite and accessory magnetite, and is thus a potash granite. Among the granites met was adamellite consisting of quartz, orthoclase and labradorite in nearly equal proportions with biotite and accessory magnetite: boulders of hornblende-biotite granite are of frequent occurrence in the stream-courses.

About three miles S.E. by S. of Pyagawpu village an interesting example of river capture was noticed. The Bilin Chaung has captured the head waters of a stream flowing northwards into the Thelaw Klo and has since continued to cut its way downwards through the alluvium and the underlying slates until, at the bend where the Bilin Chaung turns to flow south-eastwards, it is now 75 feet below the valley of the former stream, leaving a cliff of alluvium at the southern termination of the Pyagawpu valley.

Lower Chindwin district, Burma.

Mr. V. P. Sondhi mapped parts of sheets 84 J/16, J/15, J/14, N/4 and N/3, in the Lower Chindwin district, Upper Burma and recognised the following series and rock types:—

Alluvium,
Plateau Gravel and Plateau Red Earth,
Irrawadian series,
Pegu series,
Igneous rocks.

The area examined forms the catchment area of the River Chindwin, which is flanked on both sides by belts of alluvium of variable depth and width, generally consisting of a buff to brown sandy clay, resembling weathered Irrawadian sand-rock, from which

most of it is doubtless derived, though locally its lithological characters are highly variable. In the vicinity of the volcanic tuff deposits it is seen to be intimately mixed with the latter and along the river banks near Monywa (22° 7′; 95° 8′) it is frequently found to contain discontinuous bands of ferruginous conglomerate, with occasional pieces of rolled fossil wood.

Most of the country north of the North Yama Chaung, which has an easterly course in Sheets 84 J/16 and 84 N/4, is occupied by the Irrawadian series, often covered by patches of alluvial mantle consisting of an unstratified deposit of incoherent yellowish sand, sometimes stained red with iron oxide. For the most part it is pure, though varieties mixed with clay, or locally containing lenses of pure tenacious clay, are not uncommon. Discontinuous bands of hard ferruginous conglomerate and grit were noticed at several places in this deposit and locally it is found to be very rich in silicified tree trunks, which are sometimes very large. Along the River Chindwin the sand is generally hardened into a loose sandstone and often shows false-bedding.

The outcrops of the Irrawadian series are usually capped by a surface deposit of Plateau Red Earth, consisting of a brick-red sandy clay or of Plateau Gravel; the latter is the more frequent of the two, consisting of large rounded quartz pebbles with fragments of fossil wood and ferruginous concretions in a loose, reddish, gritty matrix. West of Kani (22° 27′; 94° 51′) it contains an abundance of fossil tree trunks and near Natyin Daung (22° 31′; 94° 57′) it is particularly rich in ferruginous concretions.

South of North Yama Chaung a portion of the Pegu series was examined while its junction with the alluvium was being mapped west of Monywa. The lithology of the series differs widely from the type sections in the oil fields, the rock being a bedded calcareous sandstone. The dips are very variable and cannot be relied on, on account of the great disturbance caused by igneous activity in the late Tertiary period manifest in a number of small exposures in the area.

The chief geological interest in the area centres round the varied suite of intrusive and extrusive igneous rocks, a more or less continuous line of which runs towards the north and has been followed for about 25 miles. For the last 13 miles or so they take a north-easterly direction and form a chain of extinct explosion craters which constitute a remarkable topographical feature of the country.

The igneous occurrences, which are manifested in a variety of forms, may be grouped with regard to their geographical distribution, as follows:—

1. Rhyolitic extrusion, with associated rocks, west of Monywa.
2. Songyaung explosion crater.
3. Myayeik Taung occurrences.
4. Silaung Taung basaltic mass.
5. Okkan upland extrusive and intrusive rocks.
6. Explosion craters from Leshe (22° 16′; 94° 57′) to Okaing (22° 24′; 95° 3′).
7. Natyindaung basaltic mass.
8. Isolated tuff deposits.

About seven miles W.N.W. of Monywa, in Sheet 84 N/4, a couple of hump-shaped hills stand conspicuously above the surrounding plain north of the Ywashe-Yinmabin road. They are composed of highly weathered rhyolitic tuff and agglomerate with occasional blocks of rhyolite, and seem to have undergone hydrothermal alterations resulting in the introduction of copper ore, which was changed later into malachite and chalchanthite, occurring as veins and impregnations in the tuff and sometimes containing disseminated grains of pyrite.

The low ground between the two hills is occupied by a highly decomposed mica-hornblende-porphyry, traversed by veins of calcite; at the northern end of Hill "994" there occurs a pink quartz porphyry in the form of a dike partly running into the North Yama Chaung.

Half-a-mile north of Mogyobinkanbya (22° 3′; 96° 3′) a highly denuded conical hill of rhyolitic tuff and breccia is described by Mr. Sondhi as cutting through the Pegu sandstone, and another of rhyolitic tuff and agglomerate cuts through the sandstone of the same series two miles E.S.E. of the village.

Two miles east of Songyaung (22° 13′; 95° 3′) on the right bank of the River Chindwin, opposite Alon, is a low N.E.-S.W. hill with a gentle slope on all sides except the north where it ends abruptly over a shallow lake, with a scarp about 100 feet in height, deeply truncated near the north-eastern end and marking the site of an extinct crater. That part of the hill which abuts on the river is composed of a highly jointed, comparatively fresh, dark, olivine basalt, which under the microscope is seen to contain well-developed olivine phenocrysts in a ground-mass consisting of felspar laths,

minute grains of olivine and augite, and magnetite dust. A little away from the river the rock becomes highly scoriaceous and vesicular. Further west it is replaced by a very characteristic bed about 6 feet thick, of lapilli held together by a sparse amount of an easily weatherable cement composed of volcanic ash. South-west of the lapilli bed there is a deposit of pyroclastic material, consisting of a number of unconsolidated beds of basaltic tuff, with a quantity (which varies in different beds) of rounded quartz pebbles, sand and occasional pieces of fossil wood. At different horizons in this deposit there occur beds of fine volcanic dust and ash, which are often finely laminated. Repetition of the beds of coarser pyroclastic material and laminated volcanic dust marks the different phases of the explosive energy of the crater, and suggest that the material was deposited by a series of rapid explosions of varying intensity and short duration.

The bulk of the deposit is composed of tuff with small basalt fragments, the general paucity of large blocks being very conspicuous. It is greenish brown when fresh but becomes darker on the weathered surface. The general dip of the deposit is to the south but near the centre of activity it is variable in direction as well as in degree. Some natural caves between the bedding planes, and a few small faults were observed, the latter being probably caused by subsidence of the cave-roofs.

One mile west of Myayeik (22° 8′; 95° 1′) is a group of three small elevations known as Myayeik Taung. The main hill is composed of silicified rhyolite with blocks of quartzite on its northern side. The small hill to the west is of shattered quartzite and highly altered basalt, and in the Yamadaw Chaung in the south-west there is exposed a white rock composed of decomposed felspar in which crystals of biotite are very prominent. One mile W.S.W. of this, quartzite and basalt are again exposed in a section along the North Yama Chaung.

East of Myayeik there is another small hill of purple quartz porphyry with specks of white decomposed felspar and hexagonal plates of glistening biotite.

About one mile north of Silaung (22° 10′; 94° 59′), Mr. Sondhi reports, is a plateau-like elevation about $1\frac{1}{4}$ miles long and $\frac{3}{4}$ mile wide. It is composed of a dark-grey olivine basalt similar to that of Songyaung crater, but unaccompanied by lapilli or tuff. On the other hand pink calcareous sinter with embedded fragments of basalt,

is met with some way down the slope of the hill. It is surrounded on all sides by the alluvial plain, except to the north-west where it appears to cut through yellowish sand with fragments of grit, apparently belonging to the Irrawadian series. On the west and south-west a slightly metamorphosed granite, much decomposed at the surface, is met with in a small stream.

One mile west of Silaung Taung another broad plateau-like elevation is covered by an old green basalt, interbedded at places with quartzite. The basalt is highly decomposed but the chief interest of the exposure lies in the occurrence in it of a variety of intrusive rocks. Near Okkan (22° 11′; 94° 57′) a coarse-grained white granite, composed of an equal amount of quartz and felspar with a little hornblende, is found weathering into a crumbling white earth.

One mile east of Taungbu (22° 12′; 94° 57′) is an occurrence of granophyre, a very compact rock, grey in colour, with white crystals of felspar and shining quartz. Under the microscope an interesting gradation from the cryptocrystalline to a perfect spherulitic texture is noticeable. The interspaces between the spherulites are occupied by a crypto granular mixture of quartz and felspar, passing into a cryptographic texture on the margins of the spherulites which in turn passes to a true spherulitic texture towards the centre. The spherulitic texture is sometimes seen developing round the quartz and felspar phenocrysts. Other varieties of granophyre were met with in small streams north of Taungbu.

South of Chindaung (22° 14′; 94° 57′) the hill marked Myetthaung Daung on the map is composed of a vesicular, dark olivine basalt with phenocrysts of olivine, augite, hornblende and plagioclase, embedded in a ground-mass of the same minerals with abundant laths of felspar and a little glass occurring interstitially. It appears to rest upon the quartzite.

At Chindaung there is another hillock of a fresh, highly vesicular, olivine basalt very much finer grained than that described above.

Half-a-mile west of Chindaung a granite boss is exposed in a roughly circular outcrop of about 1½ miles diameter. It is very coarse grained, white in colour, and speckled with glistening biotite. On the west it lies in contact with quartzose grit and sandstone, presumably of the Irrawadian series, which appears to be hydrothermally affected. On the north it is overlain by a surface deposit of Plateau Gravel.

Mr. R. D. Oldham late of this Department wrote a detailed description of the geology of the explosion craters from Leshe to Twindaung,[1] to which there is little to add. The following remarks may be considered a summary of Mr. Oldham's observations, together with such additional information as came to Mr. Sondhi's notice.

A string of explosion craters, about eight in number, occurring in the form of circular pits from half-a-mile to $1\frac{1}{4}$ miles in diameter and 150 feet in depth, runs from Leshe in a north-easterly direction for about 13 miles, crossing the River Chindwin at Shwezaye (22° 21′; 95° 0′) and ending at Okaing (22° 24′; 95° 3′). The pits to the west of the river Chindwin, *i.e.*, at Leshe, Twinywa and Taungbyauk, are steeply walled by a deposit of bedded basaltic ash and tuff, about 50 feet thick and resting upon the yellowish brown sand of the Irrawadian series. The outer slopes are very gentle and are covered by the volcanic deposit for one to three miles from the crest of the crater pit. Near the margins of the deposit the latter is invariably seen to overlie the Plateau Gravel. In three of the craters, one at each of the above-named villages, the floor is partially covered by lakes, which being below the level of permanent saturation are fed by small springs oozing out near the edges.

The absence of any hard rim of basalt in these craters, saving a narrow basalt plug in the Taungbyauk crater, is very conspicuous, and it seems highly probable that the pits were originally much narrower and deeper, and that the present width and comparative shallowness are due to the gradual infilling of the pit by material washed down from the receding sides, which stand unprotected in the absence of a hard crater rim.

The Twindaung crater on the east bank of the River Chindwin differs from the rest in having a partial rim of basalt on its three sides and, on that account, of all the craters it is the deepest and the most perfectly preserved. It further differs in the nature of its ejectamenta which include, apart from the usual variety of olivine basalt met with at other places, blocks of hornblende andesite, peridotite and augite rock.

The Natyin Daung basalt mass (22° 30′; 94° 59′) occurs in the form of a double cone cutting through the Irrawadian sand, and is composed of a characteristic light grey to dark grey olivine basalt.

[1] *Rec. Geol. Surv. Ind.*, Vol. XXXIV, pp. 137—147.

The two cones are separated by a narrow depression, the floor of which is level with the surrounding plain. The southern hill, which is the smaller of the two, presents a dyke-like appearance as viewed from the south, and shows deep vertical joints, whereas on the northern slope regular horizontal joints are developed, giving the rock a perfectly bedded or platy appearance. On the northern hill the basalt is darker in colour and much scoriated.

Denuded remnants of older volcanic tuff deposits of a basaltic nature, which, judging from the distance from the craters at which they are met, must have been more extensive than the newer ones, are encountered at several places south of the Twindaung crater and at Bambwe (22° 13′; 95° 0′). Their general outward appearance and curvature suggest that the craters from which they originated occupied very much the same position as do the existing ones.

On the east bank of the river Chindwin, opposite Natlabo North (22° 18′; 95° 2′), a cliff of basaltic tuff, similar to that of the other craters, stands conspicuously over the river, accompanied by huge blocks of basalt. The latter suggest the proximity of the source, but no crater was actually found in the vicinity.

It may be noted that in the area under consideration more than one period of igneous activity is noticeable, and that the youngest approximately coincided with the older in geographical position. The older, or late Tertiary, activity is represented by a more or less complete cycle as under:—

(1) The extrusive phase—including the isolated basaltic tuff deposits at Bambwe and south of Twindaung, the older basalt of the Okkan upland and the rhyolitic extrusions west of Monywa.

(2) The plutonic phase—including the granites of the Okkan upland and west of Silaung Taung.

(3) The dyke phase—including the granophyres of the Okkan upland, the quartz porphyry and mica-hornblende-porphyry east and south of Myayeik.

The most recent volcanic activity is manifested by the extrusive phase only, and is represented by the existing crater pits and their ejectamenta, including the Natlabo tuff deposits which rest upon the Pleistocene Plateau Gravel.

The olivine basalt masses which cut through the Irrawadian sand-rock, and the older basalt at Silaung Taung, Myetthaung Daung,

Chindaung, and Natyindaung, are comparatively fresh and undecomposed, and are much younger than the green basalt of the Okkan upland, but there is no evidence to show how far these basaltic extrusions are connected with the latest or post-Pleistocene period of igneous activity.

After short instructional visits to Yenangyaung and Singu where he studied the Tertiary type sections, Sub-Assistant B. B. Gupta resumed survey work in the Lower Chindwin district, completed sheets 84 J/15 and J/16 and mapped part of sheets 84 J/11 and J/12.

The greater part of sheets 84 J/15 and J/16 is occupied by rocks of the Irrawadian series. In the northern part of sheet 84 J/15 there is an inlier of the Pondaung stage and in sheet 84 J/16 there are some igneous outcrops. The rest is covered by Recent deposits. Loose sandstone, grits and ferruginous conglomerate are the chief components of the Irrawadian, though subsidiary beds of shale are not infrequently found. Indurated sandstone was noticed in the river bed near the village of Thanlegyi (22° 12′; 94° 54′, approx.) and also in a *nala* about half-a mile south of the village. Wazin Taung is composed of Irrawadian rocks, some of the lower beds being metamorphosed as a result of igneous intrusions in the area. A vertebrate fossil, provisionally preferred to *Mastodon*, was found about three-and-a-half miles E. 10° N. of Nyaunggaing (22° 12′; 94° 47′ 30″, approx.). Fossil wood is plentiful throughout the area covered by the two sheets.

The Pondaungs are represented in sheet 84 J/15 by sandstones and conglomerates of the usual type, no fossils being found in them. On the western boundary the Irrawadian appears to rest unconformably on the Pondaung. In sheet 84 J/16 basalt and olivine basalt tuffs were noticed about a mile south of Obo (22° 10′; 94° 54′ 30″, approx.), the chief component of the tuff being olivine basalt. The cementing material is calcareous and quartz was noticed under the microscope. Basalt was also found in the pass between the two conical hills south of Wazin Taung. Decomposed biotite granite was noticed north-east and south-west of Wazin Taung and a very small outcrop of dolerite was seen cutting through the granite exposed north-east of Wazin Taung.

The rock formations met with in sheet 84 J/11 are Irrawadian, Pegu, Yaw Shales and the Pondaung Stage. The last three have

a general westerly dip and crop out consecutively, a scarp forming the eastern boundary of the Pegus. The Irrawadians are faulted against the Pondaungs by a strike fault which runs approximately north and south. The Pegus are chiefly composed of massive muddy sandstone with intermediate thin bands of rather arenaceous shale. Because of insufficient fossil evidence they have not been differentiated. Current-bedding was noticed in the sandstone in some of the sections. A narrow outcrop of Yaws, about half-a-mile wide, was mapped; the rocks are chiefly unfossiliferous shales. Sandstone and conglomerates predominate in the Pondaungs. The constituent pebbles of the conglomerates are rather smaller than those seen in the inlier noted above or those noticed in the Myaing area. The general tinge of the sandstones is greenish, while a reddish earth results from the decomposition of the argillaceous beds. No fossils were found in these rocks.

The area west of longitude 94° 35′ on sheet 84 J/12 was surveyed by the late Captain F. W. Walker during the 1922-23 field season (*Rec., Geol. Surv. Ind.*, Vol. LVI, p. 41). Of the remaining portion the north-eastern corner was mapped by Mr. B. B. Gupta during the period under report. Pondaungs and Irrawadians were the only formations mapped. The fault between the Pondaung stage and the Irrawadian, noticed in sheet 84 J/11, was traced as far south as the Tinzon Chaung, west of Kabyu (22° 12′ 30″; 94° 40′). A vertebrate fossil referred to *Stegodon* was found south of Kabaing (22° 12′ 30″; 94° 41′, approx.).

At the request of the Government of Burma, the former practice of having an officer of the Department stationed permanently at Yenangyaung has been revived. Throughout the year under report Mr. C. T. Barber acted as Resident Government Geologist, Yenangyaung, and as Official Member of the Yenangyaung Advisory Board.

Resident Geologist, Yenangyaung Oilfield.

In addition to his advisory duties Mr. Barber submitted several confidential reports on various subjects.

During the field season of 1926-27 Mr. Tipper took over temporary charge of the Central Provinces and Central India Party while Dr. Fermor was in charge of the Office.

Central Provinces and Central India.

**Chhindwara district.**

Mr. Crookshank continued his mapping in the northern Satpura tract, the ground surveyed including portions of sheets 55 J/10 and J/14, and lying mainly in the northern part of the Chhindwara district, but partly in the southern part of the Narsinghpur district. The ground surveyed was occupied entirely by Gondwanas and Deccan Trap, in the proportion roughly of 3 : 1.

The Gondwanas are referred by Mr. Crookshank wholly to the Mahadeva division, and the observed thickness in the scarps east of the Dudhi river is some 1,600 feet. These strata can be divided into two fairly well defined sub-divisions, of which the upper lies to the east and consists of about 300 feet of fine-grained sandstone with carbonaceous clays and a little conglomerate. In these strata fossil-plants are abundant, and some dozen different species were collected; the specimens have been forwarded to Professor Sahni for identification.

The lower sub-division is best seen to the north and west, and is characterised by masses of coarse conglomerate and numerous variegated clays. Normally it is unfossiliferous, but unidentifiable plant remains are fairly common in the silicified clays, which occur wherever Deccan Trap intrusives pierce this series.

The junction between these two sub-divisions is well marked on the northern edge of sheet 55 J/14. Especially is this so near Saonri, where the plane of contact is clearly an unconformity. Passing from east to west, there is no sign of any boundary. Indeed, the red clays of the lower sub-division are in places found intercalated between carbonaceous clays typical of the upper sub-division.

The Mahadevas lie almost horizontal, and such dips as have been observed are due to the disturbing effect of the Deccan Trap intrusions rather than to any regional folding. Minor faults appear to be common, and are frequently seen in places where carbonaceous beds exist and make observation easy, but no faults of importance were definitely fixed.

The Deccan Trap rocks occupy in all about one quarter of the area mapped and frequently form important hill ranges. They consist mainly of immense doleritic sheets several hundred feet thick. Dykes are also fairly common, but are much less conspicuous. In many cases they merge into the sheets. Although the tract mapped lies to the north of the country occupied by surface lava flows, Mr. Crookshank believes that two hills lying north of Kotri

may contain the remains of a true flow, although this is by no means certain. The petrology of this interesting set of intrusives is similar to that of the country noticed in the previous General Report.

Nagpur district.

During the season 1926-27, Mr. W. D. West spent four months on the continuation of his survey of the Deolapar sheet (55 O/6) of the Nagpur district, working to the north of country previously mapped, especially in the neighbourhood of Silari, Khapa, Kadbikhera, Tuyapar, Pindkapar and Karwahi. The last named village lies near the Seoni border, where Mr. West succeeded in joining up his work with ground mapped by the late Mr. Burton in 1912-13.

The general result of this season's work is to confirm the succession of strata as previously deduced and to render possible a general view of the disposition of folds throughout the southern portion of this sheet. In a generalised map it is shown that the important Silari-Salai anticlinorium of calc-granulites and calcitic marbles of the Utekata and Lohangi stages runs right across the map in an E.S.E.—W.N.W. direction. To the north of this is the Dongartal-Pindkapar synclinorium of dolomitic marbles of the Bichua stage, with an associated anticline (the Tuyapar anticlinorium) of the Chorbaoli quartzite stage, with a core of calcitic marbles and calc-granulites. Further to the north between Pindkapar and Karwahi is a belt of folded dolomitic marbles and quartzites of the Bichua and Chorbaoli stages respectively, in which the marbles occupy broad synclines and the quartzites narrow separating anticlines. To the south-west of the Silari-Salai anticlinorium is the broad Junewani syncline of dolomitic marbles. Between the Chorbaoli and Lohangi stages comes the Mansar stage or manganese-horizon, when present. From the distribution of manganese ore to the south, north and east of the Junewani syncline, and of the quartzites of the Chorbaoli stage, including the absence of the Chorbaoli stage in the belt between the Silari-Salai anticlinorium and the Junewani syncline, Mr. West deduces the existence along the northern edge of the Junewani syncline of a thrust-fault with an E.S.E.—W.N.W. strike. This deduction is perhaps confirmed by the existence of a band of fault breccia on the southern edge of the sheet some three miles E.S.E. of Pauni. A newly discovered deposit of manganese ore northwards of Deolapar and between milestones 44 and 45 on the Nagpur road falls into the correct place in

the stratigraphical sequence on the interpretation given. A general E.S.E.—W.N.W. strike of the folds has been previously noted. Towards the east side of the sheet, however, the axes of the folds are curling round to an E.N.E. direction in conformity with the general strike of the gneisses and schists to the east. The mapping indicates a gentle pitch in the folds, the direction of which is not, however, uniform throughout the country mapped. Thus the Dongartal-Pindkapar synclinorium is closed at both ends, indicating an E.S.E. pitch at the western end and a S.W. pitch at the eastern end. A study of Mr. West's map indicates that in addition to the thrust-fault already mentioned there may be at least one other parallel thrust, namely, south-west of Jhanjharia, where the dolomitic marbles of the Dongartal-Pindkapar synclinorium approach so close to the calcitic marbles of the Silari-Salai anticlinorium that a portion of the intervening strata may have been cut out by a thrust.

On the petrographical side various points may be noticed. In the Dongartal-Pindkapar belt of the Bichua stage, which, broadly speaking, consists of dolomitic marbles, many interesting mineral assemblages are found. These include anthophyllite-schists, anthophyllite-spinel-chlorite-schists, grossularite diopside-microcline-granulites and wollastonite-grossular-vesuvianite-diopside-granulites. Wollastonite does not appear to have been recorded before from the Sausar series, while the grossularite-vesuvianite assemblage appears not to be common in regional metamorphism.

The rocks of the Chorbaoli stage in the country between Pindkapar and Karwahi include not only muscovite-quartz-schists but also glassy quartzites often carrying microcline, the two rocks replacing one another laterally along the strike and also across the strike. It is not known whether these changes are due to original differences of composition or to different response to metamorphic forces in accordance with which microcline has in places been converted by pressure into muscovite.

Concerning the origin of the calc-granulites (Utekata stage) Mr. West has an important suggestion to offer. These calc-granulites are usually regularly banded with layers that are alternately characterised by labradorite and microcline felspar. Dr. Fermor and the late Mr. Burton have interpreted these rocks as due to the *lit-par-lit* injection of calcareous sediments by an acid igneous intrusive, the labradoritic layers representing the original sedimentary

bands and the microclinic layers the intrusive bands. Mr. West has hitherto accepted this explanation, but now suggests the possibility that the banding is due to some kind of seasonal variation during sedimentation. In the centre of the Silari-Salai synclinorium are magnetite-biotite-gneisses similar to those that have been regarded in the Sausar tract as representing the igneous rock that was responsible for the formation of the calc-granulites by *lit-par-lit* intrusion. In the calc-granulites adjacent to his magnetite-biotite-gneisses Mr. West has found similar magnetite granules in both the labradoritic and microclinic layers, and he considers that this shows that the calc-granulites and the magnetite-gneisses are closely related; the evidence rather suggests that this close relationship is due to the rocks being part of a sedimentary succession, which varies from a gneiss at the bottom to calcitic marbles at the top, with banded calc-granulites as an intermediate variety.

**Nagpur and Bhandara districts; Central Provinces.**

For several years Sub-Assistant D. S. Bhattacharjee has been engaged in surveying portions of the Nagpur district situated upon the Ramtek belt of country occupied by the Sausar type of schists, which lie exclusively to the north of the main line of the Bengal-Nagpur Railway. Towards the end of the previous field season, Mr. Bhattacharjee commenced work on the Maunda sheet (55 O/8) surveying the north-west corner. During the present season he has completed this sheet and also surveyed a portion of the western margin of the Bhandara sheet (55 O/12). Practically the whole of this tract lies to the south of the Bengal Nagpur Railway line and is occupied, where not obscured by alluvium, almost exclusively by Archæan rocks, of which the metamorphic schists belong to a somewhat different type from those of the Sausar belt. In grade of metamorphism they are comparable with portions of the Chilpi Ghat series with which they are probably in stratigraphical continuity. They have been previously treated by Mr. P. N. Datta, who made some years ago a general survey of this part of the Central Provinces, as belonging to the Dharwars, and it will be convenient to continue to refer to the phyllites and schists of this belt as Dharwars until their exact relationship to the Chilpis and to the Sausar series has been proved. Although the country is largely covered by alluvium there are numerous exposures to be found in stream-beds and also a certain number of small hill ranges in which the rocks are

exposed. The general strike of this belt, which may be referred to as the Bhandara belt of the Dharwars, is E.N.E.—W.S.W., parallel to the strike of the Ramtek belt of the Sausar series to the north; it is anticipated that a careful examination of the border country between the two belts may lead to an elucidation of their relationships. Excluding a small area of Deccan Trap with underlying Lametas encroaching upon the south-western margin of the Maunda sheet, the whole of the country surveyed consists of Archæan rocks with overlying alluvium. The Archæan rocks have been subdivided by Mr. Bhattacharjee into the following lithological groups:—

(1) Amphibolite,
(2) Chilpi Ghat series (Dharwars), classified provisionally into five types of zones—(*a*) felspathic muscovite-quartz-schists with tourmaline and lenticles of vein quartz carrying wolfram, (*b*) quartzites, phyllites and slates, of which the argillaceous rocks contain a few knots of sericite and crystals of magnetite and garnet, (*c*) highly ferruginous quartzite zone; (*d*) coarsely knotted sericitic zone, and (*e*) coarsely quartzitic zone.
(3) Amphibole-schists in which the amphibole is often actinolite.
(4) Crystalline series consisting of gneisses, granite, pegmatites, vein quartz and muscovite-schist.

It has not yet been possible, on account of the detached nature of the occurrences, to decipher the sequence of rocks in this tract, but it is evident on general grounds that the rocks may be equivalent to a portion of those in the Ramtek belt, except for the complete absence of manganese-ores and manganese-silicate-rocks and of the calc-granulites and various marbles, unless some of these latter are represented by the actinolite-schists. Allowing for this difference in composition, Mr. Bhattacharjee supposes that the differences between the two rocks are otherwise functions of intensity of metamorphism, and that the equivalents of the various types of metamorphic rocks in this belt are to be found in a more highly metamorphosed form in the belt occupied by the Sausar series in the Ramtek country to the north. The zone separating these two belts is largely covered by alluvium; nevertheless there are outcrops of rock and had there been a conglomerate, indicating an unconformity between the rocks of the two belts, exposures of

such should have been found. Further light on this problem is likely to be thrown by the next two field seasons' work in this portion of the Central Provinces.

Rewa State, Central India.

In his journey to the corundum deposits of Pipra in the south-east corner of Rewa State from Mirzapur on the East Indian Railway, Dr. Dunn records his impressions of the rocks traversed. The first rocks passed over after leaving the Gangetic alluvium were the Vindhyans. These persist to the Son River, after crossing which Archæan rocks are found. The country for the first few miles south of the Son River is made up of quartzites, banded hæmatite-quartzites, jaspery quartzites, slaty shales and innumerable basic traps, apparently contemporaneous, all striking east and west. One or two small outcrops of limestone were also seen. This series has been correlated with the Bijawars on the old map, but Dr. Dunn was struck with its similarity to the unaltered representatives of the Iron Ore series of Singhbhum. Passing south from this area of vulcanicity these rocks merge imperceptibly, without any apparent stratigraphical break, into an immense sequence of slaty shales, striking east and west from Mirzapur district into Rewa State. Near the Rehr River valley these become gradually metamorphosed and finally a gneissic-granite is passed over. In the Rehr River valley small patches of the Lower Gondwana rocks are seen to rest upon this gneissic-granite and other metamorphic rocks.

In the vicinity of Pipra the dominant rock-type is the above granite which is apparently intrusive into all the other Archæan representatives.

Apart from the gneissic granite the most abundant rock-type is hornblende-schist. Outcrops of this have been alluded to as dykes, but a close examination convinced Dr. Dunn of the intrusive relation of the granite to them. Their linear arrangement, as in other parts of India, is, in Dr. Dunn's opinion, due simply to their excellent cleavage and to the fact that the granite has intruded into and separated them along the cleavages.

In close association with the corundum deposits, the most abundant rock-type is a sillimanite-schist usually containing euphyllite, corundum, rutile and tourmaline. An enstatite-bearing rock is also found; this is an enstatite-quartz-rock with or without plagioclase felspar, and often with diopside, the two pyroxenes at

times showing an alteration to hornblende. Deep brown biotite is almost invariably present. As a further stage in the metamorphic development of these enstatite-bearing rocks, there are several types which show distinct peculiarities and occur simply as small "segregation" masses in the enstatite-bearing rock. They include pure enstatite-quartz-rocks, enstatite-cordierite-rocks, garnet-sillimanite-cordierite-quartz-rocks, garnet-diopside-quartz-rocks, etc.

It is possible that the sillimanite-schist and the corundum bed form a highly metamorphosed aluminous, perhaps bauxitic, series of sedimentary beds. The enstatite-bearing rocks, however, seem to have been derived from pyroxene-plagioclase rocks of igneous origin. Dr. Dunn remarks that it seems feasible that the aluminous clays were originally derived from this igneous rock.

**Coal-fields Party.**

The Coal-fields Party continued their re-survey in detail of the coal-fields of Raniganj and Jharia on the new 4 inches-to-the-mile maps. The survey of the Raniganj field was begun in the cold weather of 1925-26 and will be completed in the cold weather of 1927-28. Of the 25 sheets which cover this area 12 have been completed, 2 are awaiting the result of boring records, 3 have been partially surveyed, and the remainder lie in country where the geology is simple. The Raniganj party consisted of Rai Bahadur Sethu Rama Rau, Messrs. E. R. Gee, A. K. Banerji and J. B. Auden, Assistant Superintendents, under the control of Dr. C. S. Fox, Officiating Superintendent. Mr. Sethu Rama Rau has mapped the western end of the field and is continuing his work eastwards along the south side of the Damuda river. Mr. E. R. Gee has been working eastwards from the Barakar River and north of the Grand Trunk Road; although his work covers the most complicated tract of the coal-field he has mapped the largest area. Mr. Banerji has mapped the country astride the Barakar River and is continuing eastwards along the north of the Damuda River and south of the Grand Trunk Road. He is making a petrological study of the sedimentary strata in addition to his normal work of elucidating the structure of the upper Damuda strata. Mr. J. B. Auden was attached to the Coal-fields party for training and has proved a valuable acquisition. He has been re-examining the tract astride the Barakar River in an endeavour to arrive at a satisfactory correlation of the coal-seams on each side of the river. The delay in unravelling this area is due to lack of exposures

and a want of reliable data from bore-hole records. Two borings are to be put down shortly and it is expected that with the information thus obtained a reliable correlation will be possible. The structure has been worked out with great care by Messrs. Gee, Banerji and Auden in consultation with Dr. Fox on the ground. As a result of these visits of inspection and discussion in the field the Raniganj party have come to the conclusion that the Barakar stage is conformably overlain by the Ironstone Shale stage and that the true Barakar-Ironstone Shale boundary must lie south of the Grand Trunk Road at Begunia. An observation by Dr. Fox in regard to the false-bedding in the Barakar sandstones has provided the clue which enabled the unconformity suspected by W. T. Blanford to be satisfactorily accounted for. It has also been necessary to revise our opinion in regard to the fossil wood bed in which the specimen of *Dadoxylon* was found three years ago. It was then thought that the fossil-wood sandstone was at the base of the Panchet series in spite of the fact that the palæntological evidence indicated a Palæozoic age. Messrs. Gee and Banerjee north of the Damuda, and Mr. Sethu Rama Rau south of the same river, have found that the fossil-wood sandstone is a definite horizon throughout the middle western tracts of the Raniganj coal-field, and undoubtedly part of the Raniganj stage. Dr. Fox visited several exposures and in view of a local unconformity above the fossil-wood horizon, the evidence of the fossils, and the remarkable parallelism between the fossil-wood bed and the Narsamuda-Patmohna coal-seam below it, has come to the conclusion that the fossil-wood sandstone should be relegated to the Raniganj stage.

The new 4-inch maps of the Jharia coal-field were not available until towards the end of the season, 1926-27, when Dr. Fox began the geological re-survey of the Jharia area. Of the 8 sheets which comprise this field he has already surveyed two sheets and surveyed more than half of two other sheets. He hopes to complete the mapping of the field during the season, 1927-28. In the course of his work in the north-western corner of the Jharia field among the Talchir beds Dr. Fox found that striated or scratched pebbles were exceedingly rare among the glacial boulder beds; he observed no faceted pebbles. The pebbles consist largely of granitic material and very rarely of quartzite. There are several pebble beds in the lower Barakar stage and it was thought that these beds were resorted Talchir débris, but an examination of the pebbles shows

that they are practically all of quartzite; granite pebbles have not been noticed.

The Department is indebted to Mr. J. E. Phelps of Jealgora who spent considerable time and trouble in collecting pebbles and boulders from the sandstone overlying No. 17 coal seam in the Barakar stage in the Jharia coal-field, with a view to the elucidation of their origin. Some of the pebbles shewed distinct facets, but since nearly all of these were found to coincide with joint planes, it was the general opinion that there was no conclusive evidence of glaciation.

The coal-seams in the Barakar stage have proved to be less irregular than was imagined from previous information. It has also been found that the base of the Barakar stage includes beds which were earlier thought to be carbonaceous strata in the Talchirs. There is thus no evidence of plant fossils in the Talchirs of the north-west corner of the Jharia field as previously supposed.

The work has advanced far enough to show that there will be considerable differences in the numbering of the coal-seams with regard to the old maps, but Dr. Fox is of the opinion that a re-numbering of the seams will lead to confusion and for the present no change in the recognised number of a seam is to be made. In many cases a conglomeratic sandstone is found lying immediately on a coal-seam with large quartzite pebbles resting on the coal. The field evidence indicates that the substance of the seam must already have become coal before the pebbles were deposited on it as the pebbles have not sunk into the coal.

In addition to his work in the Raniganj and Jharia coal-fields Dr. Fox's duties in connection with the new coal-fields memoir took him to the coal and lignite areas of the Punjab, Rajputana, Baluchistan and upper Assam. In his opinion the coal of Tertiary age in north-western India is of one horizon, the so-called Laki stage (middle to lower Eocene). A great area of marshland and lagoons appear to have covered this region in Eocene times.

It is Dr. Fox's opinion that although the lignite of Palana (Bikanir State) may have accumulated on the tracts on which the vegetable matter once grew, this cannot be true of the brown coal of Isa Khel nor of the highly bituminous coal of the Salt Range and Baluchistan. In several localities the coal-seam is seen to be intercalated between shales containing marine fossils. Even in the case of the lignite of Palana it is thought likely that the vegetable material, after

conversion into mature peat, has been transported in water, probably in the form of gelatinous material, and deposited in shallow coastal lagoons or in the quiet waters of a gulf. These north-western coals are rich in volatile matter, relatively low in ash if worked cleanly, and remarkably high in organic sulphur. They are exceedingly friable and therefore do not stand transportation or weathering. They would do well for the manufacture of gas but are clearly not suitable in a raw condition for steam raising or simple combustion. If care be exercised in picking out the dull shaly coal the remainder gives a coke of fair quality.

In connection with Dr. Fox's visit to Assam, he reports that the coal-field beyond the Namchik, discovered in 1911 by Dr. E. H. Pascoe and Mr. G. Webster, is far more attractive than many have supposed. Dr. Pascoe's opinion that it is an important area has been fully proved by the work of the geologists of the Burmah Oil Company beyond Namchik, where they have found, according to their estimates, over 25 million tons of good coal in a gently inclined thick seam. The working of this seam will not involve pumping, as the seam is above the drainage level of the surrounding country. The tract is at present somewhat inaccessible. It is evidently the same seam as is found in the "Coal-Measures" of the Makum coal-field. In a new quarry, Tipong Pani, Dr. Fox found a thin band containing gastropods, including a doubtful *Natica* in a shale band above the 20-foot seam. The true age of these Assam "Coal-Measures" has never been accurately fixed but the provisional view is that they are the equivalents of the Pegus of Burma and therefore probably Miocene.

After completing his work in the Makum, Jaipur and Nazira fields, Dr. Fox visited Badarpur, where the "Coal-Measures" contain petroleum instead of coal. He accompanied Mr. H. M. Sale to the Kanchanpur boring, about 25 miles S. S. W. of Badarpur. to collect fossils from a horizon which Mr. Sale had found in 1921. Dr. Fox with Mr. Sale's assistance brought away a fair collection of fossils. These have been provisionally ascertained by Sub-Assistant P. N. Mukherji, to indicate an upper Oligocene rather than a Miocene horizon for the fossil bed and incidentally for the petroleum-bearing "Coal-Measure" beds. In the Makum field at Bara Golai near Margherita oil has been struck in a well at a depth of nearly 2,600 feet below the coal of the Coal-Measures. Dr. Fox remarks that it is thus possible that although the petro-

leum horizon is upper Oligocene the coal seams may lie in the Miocene stage. Unfortunately the gastropods found by Dr. Fox at Tipong Pani are with doubtful exceptions unidentifiable. He has, however, made a collection of fossil plants from the coal seams of the Makum and Nazira fields. These have been sent to Professor B. Sahni for identification. Dr. Fox agrees with the writer [1] that the occurrence of coal and oil in the Assam "Coal-Measures" denotes some intimate genetic connection between these two substances.

Parts of the following Survey sheets of the Salem and North Arcot districts of Madras were mapped by Rao Bahadur M. Vinayak Rao: Nos 57 P/1, P/3, P/4 and L/13 (1 inch-to-the-mile).

Madras.

The following formations were met with :—

Recent :—Alluvium of the Palar and smaller streams.

Archæan :—

Jalarpet intrusive: syenites, mottled gneisses and granites.
Charnockites: norites, leptynites and acid charnockites.
Gneisses and granites: hornblende gneisses, schists, etc.
Dharwars: quartzites and hornblende schists.

For a river of the size of the Palar the alluvium is neither widespread nor of any great thickness. There is little doubt that it has changed its course in this region. Beds of sand, conglomerate and clay are found in the valleys of streams where they debouch from the hills. Intrusives of the Jalarpet series were found extending from south of Tiruvannamalai (P/4) northward beyond Katpadi across the Palar. They consist of pink felspar pegmatites, mottled gneisses, hornblendic gneisses and syenites. Some of the dykes found in this area may be of the same age as these intrusives. The mottled gneiss with biotite mica is seen in the railway cutting between Kaniyambadi and Kannamangalam (12° 45′; 79° 9′ 30″: P/1) and also west of the road from Katpadi (12° 57′ 30″; 79° 8′) to Chittoor. It is also found extending south of Tiruvannamalai (12° 13′ 30″; 79° 4′). Near Vettavalam (P/4) is found a coarse hornblendic granite which extends westward.

In the mottled gneiss are found pebbles of charnockite (mostly norites).

[1] Pascoe; *Mem. Geol. Surv. Ind.*, XL, pp. 318-324.

A thin band of syenite is found near Pallikonda, where the mottled gneiss is found at the base of the hill. A quartz felsite was noticed south of Anaikattu (P/1).

Garnetiferous leptynites and acid charnockites were found by Mr. Vinayak Rao in the hills east of Vellore. The charnockites form the mass of Tiruvannamalai Hill (P/4), and seem to extend only a few miles south of Tiruvannamalai.

In sheet L/13 charnockites of the acid variety are found along the base of the hill south of the Palar river, 3 miles east of Ambur. Charnockites also form the main mass of Pallikonda hill.

Charnockites extend along the railway line in sheet P/3, and tongues of this are found intruding the older gneisses here. The southern part of Periyamalai consists mostly of intermediate charnockites. Bands of norites are found south of the Jagkudu's Lodge at Pusimalaikuppam (12° 47′; 79° 15′. P/1). Charnockites have not been noticed north of the Palar.

The older gneisses and granites are of small extent, and consist mostly of hornblendic gneisses and granitic gneisses. They are generally contorted, and in some places, such as the eastern face of the hill about 1 mile north of Kannamangalam railway station (57 P/1), are full of garnets. Contorted gneisses are found south of the road at mile 16 from Kannamangalam to Walajah Road station. The older gneisses are found in sheet P/4, where they are intruded by the mottled and hornblendic gneisses. They are also found at the base of the hills in P/3. Small bands of Dharwars with hæmatite and magnetite were noticed by Mr. Vinayak Rao on the hill east of Sottukinni east of the Cheyyar river in P/3 as well as east of Agaram Sibbandi railway station.

Bands of quartzites are found on the western slope of the Periyamalai and Carnaticgarh hills.

**Attock district, Punjab.**

Dr. G. de P. Cotter was placed in charge of the Punjab Party and was employed in mapping the uncompleted portion of the Attock *tahsil*, Attock district (Kala Chitta and Margala Hills, and minor intervening ranges).

Portions of sheets 43 C/5, C/6, C/9, C/10, and C/13 were mapped. This has resulted in the joining up by continuous mapping of the work done by Dr. Pascoe in the Chak Dalla and Fatehjang areas (*Mem. Geol. Surv. Ind.*, XL, pt. 3, plates 71 and 73) with the Hazara map of Mr. C. S. Middlemiss (*Ibid.*, vol. XXVI). Meanwhile the work of other members of the party has carried the geological map south-

wards over the Potwar plateau to the neighbourhood of the Salt Range. The geology, as might be expected, is very similar to that of previously mapped areas. Dr. Cotter regards the Attock Slates at Attock as the continuation westward of Mr. C. S. Middlemiss' Slate series in Hazara.

The extended map of the Kala Chitta presents few new points of interest. In the south of the range, in the area mapped by Mr. H. M. Lahiri, some identifiable fossils (belemnites, ammonites, and lamellibranchs) were found, and a collection made by Field Collector, N. K. N. Iyengar. This officer also collected some poorly preserved brachiopods from the Trias in the cutting north of the first railway tunnel south of Campbellpur (Kundian line). In the north of the Kala Chitta and in the minor more northerly ranges, the Giumal belemnite beds appear to be absent.

A feature of the Trias, which was not observed in the area mapped last year is the presence of red ferruginous beds, which are associated with the fossiliferous marls from which the brachiopods mentioned above were collected.

North of the Kala Chitta are three minor ranges, *viz.*, the Kawa Gar, the Campbellpur Hills, and the Kheramar with its eastward extension the Hasan Abdal group of hills. The structure in all these is the fan structure, and anticlinal and synclinal crests are very frequently obliterated.

The Kawa Gar, according to Dr. Cotter, consists of isoclinally folded Trias and Giumals with a strip of Lower Nummulitics along the northern margin. Between the Lower Nummulitics and the Trias-Giumal complex is a belt of shales of uncertain age: they are later than the Giumals and older than the Lower Nummulitic Limestone, and may represent either the Lower Eocene (Ranikot) or the *Cardita beaumonti* beds. Unfortunately they are unfossiliferous. They appear to be more closely connected with the Lower Nummulitic Limestone than with the Giumals, but are separated from the former by a red bed which may correspond to the ferruginous pisolite. In the Kheramar the Giumals are missing, and also in the isolated hills which form an extension to the east, except in the Hasan Abdal Hill itself, in which the Giumals occur on the S. W. flank.

At the local base of the Lower Nummulitic Limestone at the eastern termination of the Kheramar, there are black shales with sparse nummulites; these are only exposed in stream sections.

In the Hasan Abdal Hill the base of the Lower Nummulitic Limestone is marked by a bed (6 ft.) of ferruginous pisolite and above this about 60 feet of soft nodular limestone containing echinoids; these appear to belong to a new species of *Echinolampas*, perhaps related to *E. lepadiformis* D. & S. In the Bajar Hill to the east a *Nautilus*—unfortunately specifically unidentifiable—was found from the echinoid zone.

Dr. Cotter, in the course of his survey, noticed several erratic blocks; the largest, 9 feet high, 10 feet long, and 6 feet wide, rested upon Triassic Limestone about 3½ miles east of Campbellpur. The block itself was of granite gneiss and must have travelled from a considerable distance, perhaps from the north of Hazara. Erratics have been previously noticed by Wynne, Theobald, and Middlemiss; the latter (*Mem. Geol. Surv. Ind.*, XXVI, pp. 45, 46) supposes the erratics of the Potwar near Jhand to come from a concealed ridge of Crystallines hidden beneath later deposits. This explanation will not suit the occurrence east of Campbellpur, and we are forced once more to consider the possibility of a glacial episode in the Punjab. Dr. Cotter also noticed some deposits of unsorted material and boulder beds south of Dhok Umre about 3 miles E. S. E. of Campbellpur.

If a glacial episode is the true explanation, it must be supposed that subsequent water action and denudation has all but obliterated its traces. No trace of U-shaped valleys or of *roches moutonnées* remains today.

Some minor corrections of Messrs. Wadia and Lahiri's maps of last season (sheets 43 C/14, C/15, and C/11) were made.

The area geologically surveyed by Sub-Assistant H. M. Lahiri in field-season 1926-27 lies mostly in the Pindigheb but partly also in the Fatehjang *tahsil* of the Attock district and comprises the whole of Survey sheet 43 C/7 and considerable portions of sheets 43 C/2 and C/6. In 43 C/6, his work lay in continuing the surveys already made by Drs. E. H. Pascoe and G. de P. Cotter.

The geological formations met with in sheet 43 C/6 are Murree beds, the Chharat series, Lower Nummulitics, Giumal beds and Trias. The lithology is similar to Dr. E. H. Pascoe's descriptions of the various formations in the Chak Dalla area[1]. The Triassic

[1] *Mem. Geol. Surv. Ind.*, vol. XL, pp. 383—388

and Giumal beds occur as inliers in Lower Nummulitic limestone which constitutes the bulk of the Kala Chitta hills. The Triassic limestone is for the most part unfossiliferous. The ochreous limestones of the Giumals immediately underlying the Lower Nummulitic limestone are in places highly fossiliferous but the organic remains are mostly in the shape of shell-markings. Among the few identifiable fossils collected are some specimens referable to *Trigonia scabra* Lam., a species also occurring in the Cretaceous beds of Southern India. The fossiliferous ochreous limestone beds are underlain by some olive or greenish sandstone also of the Giumal series. Below this sandstone and overlying the unfossiliferous Triassic limestones is a thin bed which yielded a number of bivalves, belemnites and ammonites, the last being mostly ill-preserved. Among the fossils is a large bivalve which has been provisionally identified with *Ctenostreon proboscidea* Sow., a species occurring in the Lias of Europe. Another well-preserved bivalve is a *Gryphaea,* thought by Mr. Lahiri to be related to *G. arcuata,* another common species of the European Lias. Besides the bivalves, there are belemnites and ammonites which, when worked out, may throw further light on the age of this bed. The Murree beds exposed in the sheet belong mostly to the Basal and Lower stages of the series. Some mammalian remains were collected from these beds. One of these has been identified by Dr. G. E. Pilgrim as *Amphicyon shahbazi,* a species also found in the Gaj of the Bugti hills.

The whole of the southern half of Survey sheet 43 C/2 was surveyed. The major portion of this sheet is occupied by a sandy alluvium, outcrops of rocks being confined to the north-eastern corner and along the larger stream-courses in the western half of the sheet. The formations exposed are the Chharats and the Murree series. The Chharats occur as narrow elongated inliers in the midst of Murree beds (Basal and Lower stages) which constitute the bulk of the hills to the north and north-west of Thatta (33° 35′, 72° 13′).

The geological formations mapped in Survey sheet 43 C/7 are the Murrees and the Siwaliks (Kamlial, Chinji and Middle Siwalik stages). The lithology of the beds is similar to that of the formations in the contiguous sheet 43 C/11, described in last year's report. All the beds from Murrees to Middle Siwaliks contain vertebrate remains. Fossil wood is not infrequently met with

in the Upper Murree beds which occupy a large area in the northern half of the sheet.

The general strike of the beds in sheet 43 C/7 is E.-W. and the dips mostly northerly. Three successive strike-faults have been mapped in the sheet, in consequence of which Upper Murree beds have been brought into juxtaposition with Basal or Lower Siwalik beds to the south. These faults, with the exception of the most northerly one, are traceable along the whole width of the sheet. The most northerly fault which is the westerly continuation of the main fault observed last year as running along the south flank and foot of the Khairi Murat Hill in sheet 43 C/11, when followed westwards, is seen to die out at Nathial (33° 25′; 72° 24′), but re-appears again near the western margin of the sheet. North of the faults, the beds have a general northerly dip. South of the most southerly of the faults, the Siwalik beds are exposed first in a synclinal fold pitching east and then in the dome-structure of the Khaur anticline. The Lower Siwalik beds of the western flank of the Khaur dome dip westwards beneath Middle Siwalik beds, occurring in a synclinal trough occupying the valley of the Sil river north and north-east of Pindigheb (sheet 43 C/8).

Besides regular mapping, some revision work in the area surveyed last year, was also done during the season.

**Rajputana.**

During the field-season 1926-27 the Rajputana Party consisted of Dr. A. M. Heron (in charge), Mr. A. L. Coulson and Dr. S. K. Chatterjee, Assistant Superintendents, and Sub-Assistant B. C. Gupta. Mr. Coulson continued his survey of the Sirohi State, and the other members of the party worked in the Mewar (Udaipur) State.

In Mewar the undernoted 1-inch-to-1-mile sheets of the Central India and Rajputana Survey (old numbers) were worked on: 113 (Dr. Chatterjee), 144 (Dr. Heron and Dr. Chatterjee), 145 (Dr. Heron, Dr. Chatterjee and Mr. Gupta), 146 (Mr. Gupta), 172 (Dr. Chatterjee and Mr. Gupta), 173 (Mr. Gupta) and 714 (Mr. Gupta).

Mr Gupta's work in Mewar was essentially preliminary mapping south-eastwards from Udaipur City along the line of unconformity at the base of the Delhi system, and then eastwards across the plain of central Mewar occupied by phyllites of the Aravalli system, granites and mixed gneisses. For the last six weeks of the season, he continued Mr. E. J. Bradshaw's mapping of the synclines of the Jazarpur

and Sabalpura hills [1] eastwards through Jaipur and Bundi State, in sheet No. 265, to their termination.

The non-porphyritic, medium-grained, pink granite (the Berach granite) with secondary chlorite representing the ferro-magnesians, which occupies large areas of the plain in the neighbourhood of Chitorgarh,[2] is, in Dr. Heron's opinion, identical with the Bundelkhand Gneiss; this is in accordance with the views expressed in the Manual of the Geology of India (p. 68). The Aravallis rest upon this with an erosion unconformity, and it is thus the oldest rock in Rajputana. To the west this granite gradually becomes by pressure metamorphism, a grey slabby gneiss. Further to the north, N. of Unwa ("Urwas": 24° 58′; 73° 45′) is a large exposure of the dark granite gneiss which is the dominant intrusive in the gneissic plain of Ajmer and Kishengarh.

The southern edge of the Mewar plain forms part of the main watershed of India. The slope is very gentle towards the north-east, in the direction of the Ganges valley; to the south, the fall ultimately to the Gulf of Cambay is much steeper and the country is deeply dissected, affording excellent exposures, over a distance of more than 30 miles across the strike, of the rocks which form the plain. These present a typical "gneissic complex" in which igneous rocks of several types and times of intrusion, are intimately injected one with another and the whole suite welded, while still in a plastic state, into a streaky and banded composite gneiss.

The strike of the foliation varies from N.-S. to N.N.W.-S.S.E. and its dip, in the east of the tract, is westwards, and in the west, is eastwards. This does not however indicate a synclinal disposition. Over certain areas in the western portion, the foliation is almost horizontal, but high angles approaching verticality are the general rule.

In such a complex it is difficult to ascertain the relative age of the elements, as each may have reached its present position at more than one period, and also, through pressure acting on a partly solid and partly unconsolidated association, mutual intrusion *in situ* may have taken place, involving elements of different period. The under-noted succession can therefore be considered as only an approximation to the truth.

[1] *Rec. Geol. Surv. Ind.*, LIX, pp. 104-5.
[2] *Rec. Geol. Surv. Ind.*, LIX, p. 94, LX, pp. 116, 118.

The oldest member of the complex, in which all the others are intrusive, is believed to be a gneissic granite, with biotite in about the same relative proportion to the other minerals as in an average granite. This occurs both in large masses almost free from later intrusions, and also as a composite gneiss with pegmatite and aplite in intimate interfoliar banding. Around the borders of the intrusion free masses in many cases occur which may be interpreted as sheets of the gneissic granite detached by the pegmatite and aplite. Towards the east the gneissic granite is either absent, or has become less biotitic. In the latter case it is probable that its place is taken by a medium-grained granite, little foliated and poor in mafic minerals; this, however, may belong to the pegmatites and aplites, intermediate in grain between them. It has a certain resemblance to the Bundelkhand Gneiss, but this may be purely accidental. In places a fine-grained, unfoliated granite carrying biotite occupies large areas ; this may be a fine variety of the fundamental gneissic granite.

The next in age, according to Dr. Heron, are probably the epidiorites and hornblende schists, resulting from the metamorphism of dolerite or other basic rocks. They are usually in large lenses and sheets, parallel with the general foliation, though small-scale banding with the other elements occurs in a minor degree.

In general younger than these, but no doubt belonging to more than one period, are the pegmatites and aplites, which grade insensibly into each other. Unlike the post-Delhi pegmatites, these rarely contain tourmaline or muscovite and they are never so coarse nor in such large bodies as the post-Delhi pegmatites. They all show markedly the effects of compression, and occur, for the most part, as sheets parallel to the oliation, of all sizes from a width of many feet down to a few inches. With the gneissic granite, and to a less extent with the hornblende schists, they produce composite gneisses of very variable aspect.

Last of all are the quartz veins. *In the present area,* Dr. Heron remarks, they are the only intrusives which penetrate the overlying outliers of Delhis and the Aravalli phyllites. Quartz veins have probably accompanied all the acid rocks, but those in the sedimentary series are of course of a much later epoch than those coeval with the igneous rocks of the complex, from the denudation products of which the sedimentaries were laid down.

To the east the Aravalli phyllites rest upon the rocks of the complex with what appears to be an erosion unconformity, from the

evidence of the single section which Dr. Heron has been able to find so far. To the west the main syncline of the Delhi system, with a clear erosion unconformity at its base, several outliers of the Delhi system (probably of the Raialo series) are disposed in two elongated isoclinal synclines, running north and south, not usually more than a mile wide, and one of them has been mapped by Dr. Chatterjee and Mr. B. C. Gupta at intervals for more than 30 miles along the strike. At Bhindar (24° 30′ : 74° 14′), on this syncline, basal grits and arkose, derived from the gneisses, indicate the unconformity.

The relationship of the Bundelkhand Gneiss to the mixed gneisses of the complex is not yet known, as it has so far not been found in contact with them.

The unconformity at the base of the Delhi system has this year been traced, in a general way, to the southern frontier of Mewar, though much detailed work has still to be done in the coming field-season.

The tract of complicated folding and faulting north of Udaipur City has yielded important results. It is found that the Rajnagar marble,[1] with the schists and basal quartzite below it and other schists above it, emerges from below the basal conglomerates of the main Delhi syncline, and outliers of these conglomerates rest both upon the marble and the associated schists, and upon the mixed gneisses which unconformably underlie the marble series.

As Dr. Heron points out, there is thus a double erosion unconformity, the Rajnagar marble with its associated schists and basal quartzite resting upon the mixed gneisses, and the basal conglomerates and quartzites of the main Delhi syncline overlapping both.

There is little doubt that the Rajnagar marble and its associates are identical with the white dolomitic limestone of the Jazarpur and Sabalpura hills, and of the Pur-Banera ranges, of Sawar in the extreme south of the Ajmer district,[2] and of numerous other small outliers scattered over the central plain.

In Dr. Heron's opinion the correlation may with safety be carried still further, to link up with the Raialo limestone and quartzite, which in the south of the Alwar state locally intervenes between the base of the Alwar series and the underlying granite.[3]

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[1] *Rec. Geol. Surv. Ind.*, LX, pp. 110-1.
[2] *Rec. Geol. Surv. Ind.*, LX, pp. 117-9.
[3] *Mem. Geol. Surv. Ind.*, XLV, pt. 1, pp. 23-8.

In Alwar the Alwar series and the Raialo series appear to be conformable, as there is no visible discordance of bedding, but the lowest beds in the Alwars are conglomerates, indicating surface conditions and a break in the succession[1], and the unconformity is probably present here also.

In Jodhpur State, on the other side of the great Delhi syncline, Mr. Tipper and Dr. Heron mapped extensive deposits of crystalline limestones which have a similar relationship with the Delhis and the basement of gneiss, and these may now be equated, with more than probability, with the Raialo limestone and the Rajnagar marble.[2] Further, the celebrated Makrana marble, which lithologically is very similar to the Raialo limestone, lies along the strike of the Ras limestones, though separated from them by many miles of alluvium and blown sand, and is considered by Mr. Tipper to be a continuation of them.

A wide-spread, but quite probable, correlation is thus advocated between all these occurrences of white dolomitic limestone in Rajputana, bringing them all under the Raialo limestone. As, in Mewar, the limestone has both above and below it, considerable thicknesses of other rocks, the association may be termed the Raialo series, and may provisionally be considered as the lowest division of the Delhi system, separated from the Alwar series by a distinct unconformity, which, however, is not of such a magnitude as the profound unconformity between the Delhi and the Aravalli systems.

At the beginning of the season Mr. Coulson was engaged on water-supply questions at Dabheji-Jungshahi (North-Western Ry.), Tirth Laki and Gopang in Sind, and, while on his return from Sirohi to headquarters, investigated the water-supply of Jhansi.

About 455 square miles of Sirohi State were geologically mapped during the season, on the 1-inch-to-1-mile Central India and Rajputana Survey sheets 77, 95, 96, 97 and 120 (old numbers); this is in continuation of the previous season's field-work.

The sedimentary rocks present consist of limestones and calcic rocks, mica-schists, phyllites and slates, and quartzites, and these are highly metamorphosed and profusely intruded by igneous rocks. In the hilly country to the south-east of Abu Road Railway Station, these sedimentary metamorphics are seen to be thrown into isoclines

[1] *Loc. cit.*, pp. 48-50.
[2] *Rec. Geol. Surv. Ind.*, LVI, p. 52.

and overfolds. The quartzite to the south-east of Bandia Gadh (24° 25′ : 72° 51′) is faulted into juxtaposition with the limestone on the former's northern and eastern boundaries, and brecciation has taken place along the junction between mica-schists and limestone from Abu Road, south-eastwards.

The Erinpura granite, which has been described in last year's General Report,[1] stretches south-west from the *massif* of Mount Abu into Palanpur State, where it forms the high Jaira hills. Mica-schists are found as patches surrounded by granite and represent portions of the roof of the great bathylith.

A large mass of a younger granite occurs in the south-eastern corner of the state, where it adjoins the Idar and Danta states. Mineralogically this is very similar to the Isri [2] and Waloria [3] granites and is thus probably to be referred to the Jalor granite of LaTouche.

In the south-western area of Sirohi State, especially near Padar (24° 29′ : 72° 31′) numerous dykes, striking E.—W., form a net-work with the schists and limestones striking N. E.—S. W. They cut the quartz (pegmatitic) veins from the Erinpura granite, and are thus younger than it, and may be provisionally considered as hypabyssal feeders of the Malani rhyolites. Mineralogically they are composed of sericitised potash felspar, hornblende, a little quartz, and a varying amount of iron-ore, and are rather basic microgranites, the fine-grained equivalents of the Isri (Jalor) granite to the northeast.

Two occurrences of an interesting rock new to this area were noted one mile south-east of Karari (Abu Road Railway Station) and at Chaudrawati (24° 26′ : 72° 47′); this varies from almost a troctolite (olivine and labradorite) to an olivine-gabbro (olivine, titaniferous augite and labradorite.

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# ACTINODON RISINENSIS, N. SP. IN THE LOWER GONDWANAS OF VIHI DISTRICT, KASHMIR, BY D. N. WADIA, *Assistant Superintendent, Geological Survey of India*, AND W. E. SWINTON, *British Museum, London.*[1] (With Plate 1.)

Introduction.

The present fossil was found in a small outcrop of Lower Gondwana rocks near the Risin hamlet (1½ mile E.N.E. of Zewan, Vihi district, Kashmir), not far from the site from which Noetling obtained plant and vertebrate fossils in 1902 (described by Seward and Woodward in *Pal. Ind.*, New Series, Vol. II, Mem. 2, 1905). The *Actinodon* skull occurs in association with numerous remains of fossil Ganoid fish and pteridospermous plants in a series of beds of remarkable petrographic constitution, which look exactly like, and have hitherto been described as black carbonaceous shales, but which in reality are extremely pure glassy volcanic tuffs, finely laminated for the most part.

The importance of the present find, besides the purely palæontological interest, lies in the association of indubitable Lower Gondwana fossils with a rock-group of this peculiar lithology, a circumstance which helps in fixing an important stratigraphical horizon in the Punjab range of the middle Himalaya. For a similar group of volcanic glassy tuffs and slates occurs conformably at the base of a very thick series of unfossiliferous coarse sediments, along the S.W. flank of the Pir Panjal; this latter series has been, on various grounds, ascribed to the Lower Gondwana by one of the present writers,[2] but positive evidence was lacking as the series did not yield a single indubitable fossil plant or animal.

The stratigraphical sequence in the Pir Panjal recalls in its main elements that in the Vihi district and, as Middlemiss' work has tended to prove, occurs in fact in the south-western limb of the geosynclinal of the Kashmir valley.[3] The occurrence, therefore, of the present

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[1] The stratigraphical account in the above paper is written by Mr. Wadia who collected the fossil; the palæontological description is by Mr. Swinton.

[2] *Mem. Geol. Surv. Ind.*, Vol. LI, Pt. 2.

[3] *Rec. Geol. Surv. Ind.*, Vol. XL, Pt. 3; and *Rec. Geol. Surv. Ind.*, Vol. XXXVII, Pt. 4.

fossil in a rock-series of this peculiar nature in Vihi establishes, with reasonable approximation, the Lower Gondwana age of the Pir Panjal sediments, which overlie it with perfect conformity, but which in all other respects are unlike the Vihi sediments. For, while in the Vihi area the overlying Gondwanas are barely 50 feet thick and are composed of fine-grained siliceous shales with limestones. the Panjal Gondwanas are composed of coarse conglomerates, sandstones, and sandy shales, over 5,000 feet in thickness.

Stratigraphy.

The following section, pieced together from the closely adjacent Risin and Zewan outcrops (situated about 1 mile apart, along the same strike-line) gives the stratigraphical relations of the fossil locality:

| | Strike E.N.E. to N.E. Dip 30°. | |
|---|---|---|
| Zewan stage (Permo-Carboniferous). | Sandy, thick-bedded, grey limestone with *Athyris*, *Productus*, *Protoretepora*, etc., showing rapid but perfectly conformable passage into | |
| *Gangamopteris* beds (Upper Carboniferous). | Dense, black, slaty tuff (grey or buff on exposure) containing many plants, fish, *Archegosaurus*, *Actinodon*. . . . . | 100 feet |
| | Thin lenticular limestone and chert bands . | 10 ,, |
| | Black flaggy and laminated glassy tuffs, ringing under the hammer, with *Gangamopteris* only . . . . . . . | 20 ,, |
| | Black, coarsely crystallised limestone, showing metasomatic change into flint . . | 4 ,, |
| | Green siliceous shales . . . . . | 3 ,, |
| | ------------------------------------ Conformity | |
| Panjal Trap (Upper Carboniferous). | Amygdaloidal bedded basic lava flows . . | |

The fossil fishes belong to the genus *Amblypterus*—*Amblypterus kashmirensis* A. S. W., *Amblypterus symmetricus* A. S. W., *Amblypterus* sp. indet.- and consist of impressions of cranial, abdominal and caudal regions with recognisable elements of the skulls and limbs.

The plant remains associated with the *Actinodon* are:—

*Gangamopteris kashmirensis.*
*Gangamopteris* sp.
*Glossopteris indica.*
*Vertebraria indica.*
*Callipteridium* sp.
*Cordaites* sp.
*Psygmophyllum* sp.
*Ginkgo* sp.

The chief fossiliferous zone is made up of the upper tuffs which are exposed in a series of small dip-slopes over the whole length of the hill-face, the dip of the beds—about 30°—corresponding with the slope of the latter. The lower tuffs have so far yielded only fragments of *Gangamopteris* leaves. Both these tuffs have been hitherto spoken of as carbonaceous shales, the presence of plants being assumed as sufficient evidence of the carbon content. But there is neither clay nor carbon in them, as a microscopic examination shows. The rock is wholly composed of glass particles with a few tiny crystals of felspars. The black colour is due to iron and bleaches rapidly on all exposed parts. The rock gelatinises easily with acids and splinters on the application of heat.

The rapid but perfectly conformable passage of the tuffs into the *Productus*-bearing limestone of the Zewan stage is conclusive evidence of the Upper Carboniferous age of *Actinodon risinensis.*

Palæontological account.

The specimen consists of a piece of matrix bearing the impression of the greater part of the upper surface of a Stegocephalian skull. The skull has been slightly flattened and traces of the mandibles with teeth are observable on its lateral borders. About half of the post-orbital region and the tip of the snout are missing. Despite this the condition of the features preserved is sufficient to indicate that the species is new. The general proportions are very similar to those of *Actinodon,* to which genus we propose to refer the specimen. This genus was established in 1867 by Gaudry (*Nouv. Arch. du Mus. Paris,* 1867, Vol. iii, p. 23) for some material from Autun to which, however, he gave no specific name. In the same paper (*loc. cit.*, p. 31) he drew attention to the similarity between *Actinodon* and *Archegosaurus latirostris* and figured the latter as *Actinodon latirostris.* which, accordingly, became the type species, although later French writers overlook it as such. Gaudry subsequently established the forms, *A. frossardi* (*Bull. Soc. Géol. de France,* 1868) and *A. brevis* (Les Enchainements du monde animal—fossiles primaires, Paris, 1883, p. 266). In 1910 Thévenin (*Ann. de Palaeont.*, 1910, Tome V, fasc. 1) redescribed and figured the two latter forms and showed that they represent different growth stages of a single species. The new specimen is closely similar in size to the *Actinodon brevis* stage but various features prevent its reference to any growth stage of the type species. From the locality of its occurrence we propose to name it *Actinodon risinensis.*

## Genus: ACTINODON Gaudry.

### ACTINODON RISINENSIS, sp. nov.

*Diagnosis.*—Skull slightly longer than broad with the lateral borders more convex than in the type species; orbits comparatively large and in the middle of its length the squamosal much narrower than in *A. latirostris*; squamosal border of the otic notch running more backwardly. Fronto-parietal suture anteriorly placed.

*Material.* Impression of the greater part of the upper surface of the skull. Holotype. In the collection of the Geological Survey of India.

*Horizon and Locality.*—Permo-Carboniferous basal Gondwana. Zewan Spur, Vihi, Kashmir, India.

*Dimensions.*

| | *A. risinensis.* | *A. brevis* (Gaudry's fig.) |
|---|---|---|
| Maximum length | 93 mm. | 94 mm. |
| Length along middle line | 78 ,, | 78 ,, |
| Maximum breadth | 86 ,, | 88 ,, |
| Breadth of hinder border of squamosal | 11 ,, | 18 ,, |
| Breadth across posterior edge of orbits | 72 ,, | 73 ,, |
| Breadth across middle of orbits | 64 ,, | 64 ,, |
| Breadth across anterior edges of orbits | 58 ,, | 58 ,, |
| Length of orbits | 21 ,, | 17 ,, |
| Breadth of orbits | 17 ,, | 13 ,, |
| Inter orbital breadth | 15 ,, | 13 ,, |
| Diameter of parietal foramen | 3 ,, | .. |
| Breadth of skull across nares | 33 ,, | 33 m.m |

*Description.*—The region of the skull posterior to a line joining the hinder borders of the left squamosal and the right orbit is missing, as also is the tip of the snout with the left narial opening. The impression of the greater part of the skull is, however, quite well preserved. In general size and shape it closely resembles *A. brevis* although the lateral borders of the skull are more convex than in that form and resemble those of *A. frossardi*. The whole surface is covered with a fine ornamentation in the form of small rounded pits, which occasionally—and especially in the nasals—show a radial arrangement. The impression of the left squamosal is complete and is chiefly remarkable for its narrowness, being little more than half the width of that of *A. brevis*. The squamosal border of the

otic notch is, and the notch itself appears to be, directed more backwards and to a less degree outwards than in the type species. The remaining bones of the skull call for no detailed description. The sutures are discernable with some clearness on treating the impression with a solution of Canada balsam in xylol and are reproduced as far as traceable in figure 1, Plate 1. The parietal bone is comparatively large, the fronto-parietal suture being placed further forwards than in the figures of *A. frossardi* or *A. brevis.* In Thévenin's figure of *A. frossardi* the suture is practically coincident with the line joining the posterior borders of the orbits. The parietal foramen is circular with a diameter of 3 mm. The orbits, situated in the middle of the length, are ovate and have their long axis parallel to the lateral borders of the cranium. They are comparatively large, their length being approximately two-ninths of the maximum length of the skull as against two-elevenths in the case of *A. brevis.* The impression of the right naris is completely preserved and is comparatively large; it is close to the rostral border and has its long axis directed forwards and inwards. The characters of the mandible are well seen in a cast made from the impression and are closely similar to those figured for the type species. The teeth are narrowly conical and measure about 4 mm. in length. The remaining features to be seen in the specimen are quite similar to those of the skulls described by Gaudry and Thévenin and call for no further description.

The occurrence of this new form in the locality which has already yielded the remains described as *Archegosaurus ornatus* by Smith Woodward (*Pal. Indica,* New Series, Vol. II, Mem. 2, p. 13) is interesting and it is to be hoped that further specimens from this stegocephalian fauna will be forthcoming.

## EXPLANATION OF PLATE

PLATE I. *Actinodon risinensis,* sp. nov. Upper surface of the skull as drawn from the pression, natural size. The broken line indicates restored portions. Sq.=squamosal; Au.=auditory notch; Pa.=parietal; P. f.= parietal foramen; Fr.=frontal; Orb.=orbit; Na.=nasal; Nar.=narial aperture.

# MISCELLANEOUS NOTE.

## Further Note on the Nomenclature of Hollandite.

In a paper[1] published some years ago I proposed the institution of a new group of minerals to include the crystalline mineral hollandite, its amorphous form psilomelane, and coronadite, a fibrous mineral described by W. Lindgren and W. F. Hillebrand, from the Clifton-Morenci copper area of Arizona, United States of America, the last-named mineral being regarded by me as a manganese-lead manganate, instead of as a manganite, as thought by the authors of the term. In a later paper[2] recognition was accorded to Prof. Lacroix' term romanéchite, applied to the mineral obtained from Romanèche in Central France, and it was shown that romanéchite could be suitably recognised as one variety of hollandite, if again it were regarded as a manganate, instead of as a manganite as interpreted by the author.

A discussion of the nomenclature of these minerals was summarised in the following statement:—

| | | | | |
|---|---|---|---|---|
| Hollandite Group | Pb low or absent<br>Ba low to high | Hollandite | High in $H_2O$<br>Low in $Fe_2O_3$ | Romanéchite. |
| | | | Low in $H_2O$<br>High in $Fe_2O_3$ | Hollandite *sensu str.* |
| | Pb high<br>Ba absent or low | Coronadite | | |

At this stage the problem remained until 1923,[3] when Ernest E. Fairbanks published the results of a microchemical study of polished sections of coronadite, romanéchite, and hollandite. These tests showed that both coronadite and romanéchite are mixtures of hollandite with an unidentified finely disseminated constituent.

The results of this work simplify greatly our nomenclature; for although the work of Fairbanks does not tell us whether the high lead contents of coronadite is contained in the hollandite or in the other mineral present, it enables us to reject the name as that of a mineral species. The same remark applies to romanéchite, and we can now with confidence use the term hollandite as a comprehensive term for all the known varieties of crystalline manganates. It will be time enough to admit varieties or sub-species of hollandite, when satisfactory chemical evidence of the existence of varieties of unusual composition is forthcoming.

L. L. FERMOR.

[1] *Rec. Geol. Surv. Ind.*, XXXVI, pp. 295-300, (1908).

[2] 'On the Crystallography and Nomenclature of Hollandite'. *Rec. Geol. Surv. Ind.*, XLVIII, pp. 103-120, (1917).

[3] 'Micrographic Notes on Manganese Minerals'. *Amer. Mineralogist*, Vol. 8, p. 209, (1923).

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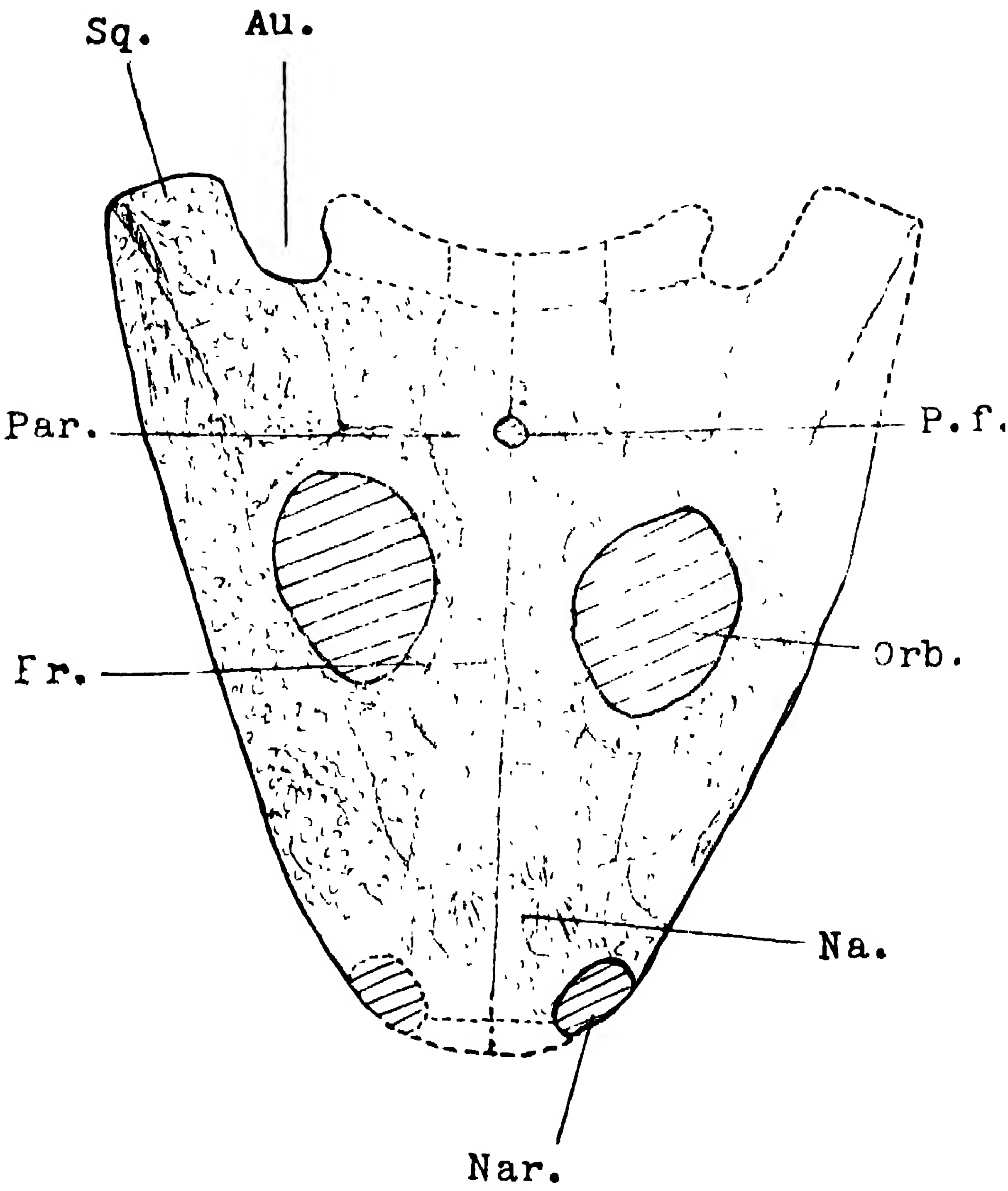


*G. S. I. Calcutta*

ACTINODON RISINENSIS, *SP. NOV.*

*(Natural size)*